THE

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OF THE

GEOLOGICAL SOCIETY OF LONDON.

EDITED BY

THE ASSISTANT-SECRETARY OF THE GEOLOGICAL SOCIETY.

Quod si cui mortalium cordi et curæ sit non tantum inventis hærere, atque iis uti, sed ad ulteriora penetrare; atque non disputando adversarium, sed opere naturam vincere; denique non belle et probabiliter opinari, sed certo et ostensive scire; tales, tanquam veri scientiarum filii, nobis (si videbitur) se adjungant. —*Novum Organum, Præfatio.*

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ERRATA ET CORRIGENDA.

Page 68, note ‖, line 1, *dele* "for which the name Duporthite has been needlessly proposed."

Page 81, line 4, *for* "albite" *read* "oligoclase."

Page 455, explanation of figure, *for* "Mowbrey" read "Moorhey."

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1. *On the* Mammalian Fauna *of the* Val d'Arno. By Dr. C. J. Forsyth Major. (Read June 25, 1884.)

[Communicated by Prof. W. Boyd Dawkins, F.R.S., F.G.S.]

Contents.

§ 1. *Introductory. The Fauna of the Val d'Arno.*

In the following essay on the fossil mammalia of the Val d'Arno I have subjected the list of species to a critical examination and brought it down to the knowledge of to-day. It will be seen from the following lists that I have been able to add a considerable number of species to those known in former years.

I. 1872 *.

Macacus florentinus, *Cocchi.*
Felis, 2 sp.
Canis, sp.
Ursus etruscus, *Cuv.*
Mustela, sp.
Hyæna, sp.
Drepanodon (Machairodus), 2 sp.
Equus fossilis, *Rütim.* (non *Owen*).
Hippopotamus major, *Cuv.*
Mastodon arvernensis, *Cr.* et *Job.*
Elephas meridionalis, *Nesti.*
—— antiquus, *Falc.*

I. 1872.

Rhinoceros etruscus, *Falc.*
—— hemitœchus, *Falc.*
—— leptorhinus, *Cuv.*
Sus, sp.
Bos etruscus, *Falc.*
Cervus dicranios, *Nesti.*
——, 2 sp.
Castor, n. sp.
Tapirus, sp.
Antilope, sp.
Lagomys, sp.

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* Forsyth Major, in Antonio Stoppani, 'Corso di Geologia,' ii. p. 673.

II. 1874 *.

Macacus florentinus, *Cocchi*, sp.
—— ausonius, n. sp.
Felis, 3 sp.
Canis, 2 sp.
Ursus etruscus, *Cuv.*
Mustela, sp.
Hyæna Perrieri, *Cr.* et *Job.* (H. brevirostris, *Aym.* ?).
—— arvernensis, *Cr.* et *Job.*
Machairodus, 3 sp.
Equus Stenonis, *Cocchi.*
Hippopotamus major, *Cuv.*
Mastodon arvernensis, *Cr.* et *Job.*
Elephas meridionalis, *Nesti.*
Rhinoceros etruscus, *Falc.*
Sus Strozzii, *Menegh.* in Coll.
Bos etruscus, *Falc.*
Cervus dicranios, *Nesti.*
—— ctenoides, *Nesti.*
——, 2 sp.
Castor plicidens, n. sp.
Hystrix, sp.
Lepus, sp.

III. 1876 †.

Macacus florentinus, *Cocchi*, sp.
—— ausonius, *Major.*
Felis, 3 sp.
Canis etruscus, *Major.*
—— Falconeri, *Major.*
Ursus etruscus, *Cuv.*
Mustela, sp.
Hyæna Perrieri, *Cr.* et *Job.* (H. brevirostris, *Aym*, ?).
Hyæna arvernensis, *Cr.* et *Job.*
Machairodus, sp.
Equus Stenonis, *Cocchi.*
Hippotamus major, *Cuv.*
Mastodon arvernensis, *Cr.* et *Job.*
Elephas meridionalis, *Nesti.*
Rhinoceros etruscus, *Falc.*
Sus Strozzii, *Menegh.*
Bos etruscus, *Falc.*
Cervus dicranios, *Nesti.*
—— ctenoides, *Nesti.*
——, 2 sp.
Castor plicidens, *Major.*
—— Rosinæ, *Major.*
Hystrix, sp.
Lepus, sp.

IV. 1883.

1. Macacus florentinus, *Cocchi*, sp.
2. —— ausonius, *Major.*
3. Felis issiodorensis, *Cr.* et *Job.*
4. —— arvernensis, *Cr.* et *Job.*
5. ——, sp.
6. Canis etruscus, *Major.*
7. —— Falconeri, *Major.*
8. ——, sp.
9. Ursus etruscus, *Cuv.*
10. Mustela, sp.
11. Hyæna, sp. (Montopoli).
12. Hyæna Perrieri, *Cr.* et *Job.* (H. brevirostris, *Aym.* ?).
13. Hyæna arvernensis, *Cr.* et *Job.*
14. Machairodus meganthereon, *Cr.* et *Job.*
15. Machairodus cultridens, *Cuv.*
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17. Equus, sp.
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23. Rhinoceros etruscus, *Falc.*
24. Hippopotamus major, *Cuv.*
25. Sus giganteus, *Falc.* (Sus Strozzii, *Menegh.*).
26. Bos (Bibos) etruscus, *Falc.*
27. Leptobos Strozzii, *Rütim.*
28. Cervus dicranios, *Nesti.* (C. Sedgwickii, *Falc.*).
29. Cervus ctenoides, *Nesti.*
30. ——, sp.
31. —— Perrieri, *Cr.* et *Job.*
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34. Palæoreas montis caroli, *Major.*
35. Castor Rosinæ, *Major.*
36. —— plicidens, *Major.*
37. Hystrix, sp.
38. Lepus, sp.
39. Arvicola, sp.

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* Forsyth Major, "Considerazioni sulla Fauna dei Mammiferi pliocenici e post-pliocenici della Toscana" (Atti Soc. Tosc. di Sci. nat. in Pisa), vol. i., pp. 39, 40.

† C. J. Forsyth Major, "Sul livello geologico a cui è d' ascriversi il così detto cranio dell' Olmo" (Archivio per l'Antropol. e la Etnol. vol. vi. 1876, p. 345).

§ 2. *Relation to the Older Faunas.*

On the boundary-line between the Miocene and Pliocene we find in southern Europe, and especially in the region of the Mediterranean, and also as far to the east as the Siwalik mountains of India, a richly developed fauna in which the *Hipparion* is the most widely spread and important representative. This fauna is met with at Pikermi in Attica, at Concud, and at Alcoy in Spain, at Oran and Constantine in Algeria, at Montpellier and Mont Léberon (Cucuron) in France, at Casino near Siena, in Italy, at Eppelsheim in Germany, as well as in Austria-Hungary, the Balkan peninsula, and in Asia Minor. Not one of the members of the fauna discovered in these localities occurs in the somewhat younger fauna of the Val d'Arno. Various relations are certainly to be pointed out. The two Pliocene Antelopes, *Palæoryx Meneghinii*, Rüt., from Olivola in the valley of the Magra, and *Palæoreas montis caroli*, in the valley of the Arno, are closely allied to species of the same genera found in Pikermi. The same intimate relation exists between the *Machairodus* of Pikermi and those of the Val d'Arno. The *Mastodon Borsoni* from Asti and the upper valley of the Arno is so closely allied to the *Mastodon tapiroides*, of Winterthur, Œningen, and Pikermi, that both forms are frequently mistaken one for the other; and in the same way the Pliocene *M. arvernensis* is closely allied to *M. longirostris*. The relation of *Equus Stenonis* to *Hipparion* has been dealt with in my treatise on the fossil horses of Italy.

The mammalian fauna of Montpellier, as we know it from Gervais's works (and which according to his final assertions also contains *Hipparion*), shows us a mixture of both faunas, and not one of transitional forms, but containing species identical with those of the Val d'Arno and others identical with those from Casino.

Unfortunately the suspicion is not to be put aside that this mixture only took place in the Museum; so that we cannot draw any conclusions from this case until the circumstances are satisfactorily cleared up.

The Val-d'Arno fauna too was spread as far as India, and we find its representatives in the Siwaliks. *Equus sivalensis*, Falc. and Cautl., seems to me identical with *E. Stenonis*, Cocchi, from the Arno Valley; the gigantic wild boar from the Siwaliks, *Sus giganteus*, Falc., is probably identical with *S. Strozzii*, Menegh., from the upper valley of the Arno. So also, according to Rütimeyer's researches, the Siwalik oxen show a great similarity to those of the Val d'Arno. Lydekker distinguishes in the Siwaliks Mio-pliocene strata (*Hipparion* &c.), so that it must be said that this distinction is based on local stratigraphical circumstances, and not merely adopted by analogy with those in Europe.

§ 3. *The Shore-deposits of the Pliocene Sea in Italy contain the same Mammalian Fauna as the Lacustrine deposits of the Val d'Arno.*

We every now and then come across the assertion that the marine Pliocenes of Italy are older than the lacustrine strata of the Arno

Valley. In the shore-deposits of the Pliocene sea, in the Lower Arno Valley, and in other parts of Tuscany and central Italy, land mammals are not unfrequently found and have been recorded by the naturalists of the last two hundred years; but their age could not be determined without the systematic explorations of modern times. At present no doubt can exist. The littoral marine Pliocene strata do contain a mammalian fauna which is identical with that of the upper valley of the Arno; a study of the fossils contained in the Tuscan museums, and of the excavations carried on by me at Montopoli (in the marine Pliocene between Pisa and Florence), have placed this beyond any doubt.

§ 4. *Relations to the Pleistocene Fauna.*

In the Postpliocene (Pleistocene) we find various connecting links with the Pliocene fauna, although, at least in Italy, not a single species of the older fauna seems to have gone over, as such, to the younger fauna. Whilst the greater number of the Pleistocene (Quaternary) mammalia are distinct from those of the Pliocene, that part of the Pleistocene fauna which is often designated as the African division of the same, appears more nearly allied to it. This division should perhaps more correctly be called the old indigenous.

First of all, the Hyænas and Felines, *Hyæna Perrieri* and *Hyæna arvernensis* from the lacustrine Pliocene of Auvergne and of the Arno Valley, stand so close to the Pleistocene Hyænas, *H. crocuta* (*spelæa*) and *H. prisca*, that they may be considered their ancestors; and the same results will probably be obtained from a careful comparison of the various Pliocene and Pleistocene (Quaternary) kinds of *Felis*.

The *Rhinoceros etruscus*, Falc., of the Arno Valley more closely resembles the Postpliocene *R. hemitœchus*, Falc. (*R. Merckii*, *pro parte*), than *R. tichorhinus*, although a study of the remains of the two first-mentioned forms found in Italy does not justify the assumption of some authors on the other side of the Alps that they are identical species. With some practice it is always possible to distinguish even isolated teeth of the upper jaw of the two forms. We often find *Rhinoceros leptorhinus* cited as a Quaternary fossil; for example, Charles Mayer cites *R. leptorhinus*, together with *Elephas meridionalis* and *Hippopotamus major*, as prototypes of the Postpliocene fauna, or, more accurately, the fauna of the "Couches de Cromer," the lowest stage of his Saharian zone. In this he groups together the following strata:—Forest-bed of Cromer, sands of St. Prest, and other French localities, lower moraines and lacustrine chalk (See Kreide) of Utznach, Dürnten, and Wetzikon in Switzerland, and the sandy freshwater marls and ferruginous gravels of the region of Asti and "Sansino" of the Arno Valley.

As regards the term *Rhinoceros leptorhinus*, it has no value whatever as a proof of the synchronism of the above-named strata, as several distinct species of *Rhinoceros* have received this name; in the Forest-bed we have to do with *R. hemitœchus*, Falc., in the

district of Piacenza with the typical *R. leptorhinus*, Cuv. (*pro parte*), in the district of Asti and the Upper Val d'Arno with *R. etruscus*.

In the same way the name *Hippopotamus major* has caused confusion. The Postpliocene remains of *Hippopotamus* are pretty generally assumed to be the same as those of the *Hippopotamus* of the Arno Valley, although such a union is not the result of recent comparisons, but a survival of Cuvier's view of the matter, who did not distinguish Pliocene and Postpliocene strata, but grouped them together under the name of "couches meubles," and who accordingly was predisposed to regard these fossils as identical. The species *H. major* was founded on the perfect skull from the Arno Valley, preserved in the Florentine Museum, and described by Cuvier and Nesti; and Cuvier pointed out the difference between it and the living *H. amphibius*. Under the same name he also cited remains of *Hippopotamus* from caves &c., although they were not so perfect as to justify such a decided statement. So long, then, as the remains of the *Hippopotamus* from caves and from other Postpliocene deposits are not proved to be identical with those of the Arno Valley, it seems unjust to designate the former as *H. major*.

In many cases, where *Elephas meridionalis* is cited from Postpliocene strata, there is a great probability of its being a variety of *E. antiquus*. The latter does not appear in the Upper Arno Valley, but it occurs together with other Postpliocene mammals in the neighbouring Val d'Ambra (near Bucine) and in the region of Arezzo.

In respect to the lignite of Leffe, in Lombardy, the greatest care should be taken respecting conclusions as to the age of the mammals; because in one Italian museum fossils are labelled in the most careless way, as coming from Leffe, while distinctly showing that they are partly Miocene and partly Eocene. *Elephas meridionalis* and *Bos etruscus* are the only mammals which I know with certainty as coming from Leffe.

§ 5. *Relations to Living Forms.*

Among the thirty-nine mammals of the Val d'Arno which I mentioned at the beginning of this essay, we find at present five genera which are extinct:—*Machairodus*, *Mastodon*, *Leptobos*, *Palæoryx*, *Palæoreas*. Not a single species is identical with those living to-day. Notwithstanding this, we find among the mammals of the Arno Valley transitional forms towards those of Pleistocene times.

The former, however, show still nearer relationships to some living faunas than to those of our Pleistocene. In dealing with this question the Palæarctic, Nearctic, Neotropical, and Australian regions cannot be considered, as there exist too few analogies for the purpose, and only the Ethiopian and the Oriental region remain open for our inquiry. *Hippopotamus* is, amongst our Pliocene genera, the only one in the present day exclusively indigenous to the Ethiopian region; and on the other hand the genus *Tapirus*, known in the Oriental region, is missing in the Ethiopian. Two other genera, *Castor* and *Arvicola*, are represented in the Palæarctic

and Nearctic regions, but, so far as we know, are missing at present in the Ethiopian and Oriental regions. All the other Pliocene genera now living are indigenous to the Ethiopian as well as the Oriental region; but, if we inspect the species more closely, we find very few allied to African forms, but on the contrary their analogies point towards the Oriental region.

Pliocene mammals are to be found at the present time, but little altered, in the most southern corner of Asia, and especially in the Sunda Islands; and there not only exists a general agreement between the two groups, but also resemblances singularly special. The peculiar Buffalo-Antelope of Celebes (*Anoa depressicornis*), as Rütimeyer has pointed out, is but little changed in form from its fossil representative in the Siwalik deposits; "with but little perceptible increase of height and weaker weapons, it repeats the physiognomy of the Siwalik *Hemibos*, even to the details of the foramina for vessels and nerves"*.

Bos etruscus, according to the same author's investigations, is a real *Bibos*, and with a few Siwalik forms is closely allied to the Banting now living in Java.

The majority of Pliocene Stags (*Cervus Perrieri*, *C. pardinensis*, *C. etueriarum*, *C. Nestii*, &c.) belong to the group of the *Axis* and *Rusa*, which now live in Malacca and chiefly in the large Sunda Islands.

Amongst all the living wild Boars, *Sus verrucosus* from Java (with *S. celebensis*) shows the greatest resemblance to the Pliocene *Sus giganteus* (*S. Strozzii*), while *Sus vittatus*, indigenous to the Oriental region, is not so closely allied to it. The Tapirs and Rhinoceroses complete the manifestation of the great accordance between the Pliocene mammals and those still living in south-eastern Asia.

This fact is all the more surprising, because the above-mentioned islands are situated in the tropics, whilst, chiefly from palæophytological reasons, we are led to infer a warm climate, but in no way a tropical climate, for our Pliocenes.

But I refrain from drawing conclusions as to the Pliocene climate from the comparison of the Indo-Malayan fauna with that of our Pliocenes, and for the following reasons:—

The facts of zoological distribution teach us that the agreement in climate and in general conditions of life in two regions isolated from each other does not imply an identity of faunas. In proof of this, Wallace has brought examples from various parts of the world†. There are, however, extraordinary facts lying much nearer to us. Corsica is not many miles distant from Italy, and the isolation of the two is diminished by the islands in the Tuscan Archipelago. The Corsican climate is similar to that in the region of the Tuscan coast, and, notwithstanding this, Corsica shows in her mammals,

* L. Rütimeyer, "Beiträge zu einer palæontologischen Geschichte der Wiederkauer, zunächst an Linnés Genus *Bos*," in Verhandl. naturf. Gesellsch. in Basel, iv. p. 299 (1865).

† 'Island Life,' p. 5, &c.

amphibians, and reptiles, a closer relation with North Africa than with peninsular Italy.

On the other hand, we have no right to postulate, as a matter of course, an agreement in the climate and the general conditions of life where we find an agreement between the animal forms of two distant regions, as Mr. Wallace has shown in several surprising cases*. These facts, deduced from a consideration of the present fauna, lead us to similar conclusions with respect to the fossil faunas. Southern France, on the northern flank of the Pyrenees, and the northern half of Corsica are in the same latitude and have almost the same climate. The mountain regions of both territories were covered with extending glaciers during the Quaternary (Pleistocene) age. And yet what a difference in the Postpliocene mammalian fauna! In the caves of the south of France we meet with circumpolar mammals amongst others. In the breccias of Corsica we meet an animal of Miocene type (*Myolagus*), belonging to the Hare family, and besides this peculiar forms which have not appeared anywhere else in Europe.

If we look with this light at the fauna of the Val d'Arno, which we have seen to have been spread over Europe and Asia in Pliocene times, it also seems probable that it extended then as far as Java and Celebes. We doubtless have to thank isolation for the fact that the close relations of the mammalian fauna of the Indian Archipelago with those of the Pliocenes are preserved till the present time.

§ 6. *Conclusion.*

A few mammalian species do not always fix the geological age of the bed to which they belong. In the case of the abovementioned *Myolagus sardoüs* of the bone-breccias of Corsica and Sardinia, we have a Miocene animal, found at Œningen, Sansan, Steinheim, and Casino, which has apparently been preserved without change in the above islands down to Pleistocene times, and probably also to the Neolithic age †. In dealing with the Pliocene mammalia we have shown that several animals have been preserved almost unchanged to the present day; it may therefore be inferred that they lived, in the Pleistocene age, in areas adjacent to those spots where they now live. In the Sunda Islands, and presumably elsewhere, it would be difficult, if not impossible, to distinguish the Pliocene from the Pleistocene fossil mammalia. This may perhaps explain the fact that *Elephas meridionalis* is associated with a younger fauna on the other side of the Alps than in Italy, although the proof that this species lived in Pleistocene times in France and England, does not seem to me to be sufficient. On the other hand it is accepted by the Austrian geologists and palæontologists that *Mastodon arvernensis* appears in Austria and Hungary in a fauna

* 'Island Life,' pp. 64–67, 370, 371, 375, 378, &c.

† See Forsyth Major, "Die Tyrrhenis. Studien über geographische Verbreitung von Thieren und Pflanzen im westlichen Mittelmeergebiet" (in 'Kosmos,' vii. Jahrgang, 1883, p. 697).

which is older than the mammal fauna of the upper Val d'Arno. It may therefore be concluded that this species is geologically older in Austria and in Hungary than it is in Italy. The occurrence of a single species in distant or isolated regions cannot be taken to prove that the strata in which it occurs are contemporaneous. A species can only survive under favourable conditions, among which isolation counts before anything, as in the case of the *Myolagus* of Corsica and Sardinia.

§ 7. *Note by Prof. Boyd Dawkins.*

In this valuable contribution to our knowledge of the Pliocene mammal-fauna of Italy, Dr. Forsyth Major draws attention to the sharp line of definition between the Pliocene and Pleistocene, and considers that no species passed from the one to the other in Italy. In this I am unable to agree, because two of the Cervidæ, *Cervus etueriarum* and *C. Perrieri*,* are undistinguishable from varieties of Deer belonging to the *Axis* and *Rusa* type now inhabiting the Oriental region.

Nor can I agree with him in viewing the *Hippopotamus major* of the Val d'Arno as having been assumed to be identical with the living *H. amphibius* on the strength of a Cuvierian tradition. I have attempted in vain to distinguish between the fossil and the living forms, and after detailed measurements and a careful comparison of those from the Val d'Arno in the British Museum with the living, and after an examination of those in the Museum of the Jardin des Plantes in Paris, I am obliged to believe that they belong to the same species. *H. amphibius* must therefore be counted as a living species dating back from the Pliocene age. Numerous Pliocene species, *Elephas meridionalis, Rhinoceros etruscus*, &c., as I have already pointed out in various papers read before the Society, undoubtedly occur *in situ* in the Forest-bed of Norfolk and Suffolk, in association with Pleistocene forms, and prove the overlap of the Pliocene and Pleistocene groups. I have also shown † that the Oriental region is that in which the Pliocene mammalia of Europe find their nearest analogues.

With regard to the nomenclature of Rhinoceros, Dr. Forsyth Major's criticism applies only to the *R. leptorhinus* of Cuvier, and not to the *R. leptorhinus* of Owen, which is the equivalent of the *R. hemitœchus* of Falconer.

* Quart. Journ. Geol. Soc. 1878, p. 407.
† Ibid. p. 419.

2. *On some* Recent Discoveries *in the* Submerged Forest *of* Torbay. By D. Pidgeon, Esq., F.G.S. (Read November 5, 1884.)

Among the numerous examples of submerged forests which occur at intervals all round the English coast, there is none, perhaps, better known than that of Torbay. This has been described by De la Beche, Godwin-Austen, and many other geologists, but more particularly by Pengelly, who has given considerable attention to it and speaks * of it as follows:—

"Considerable accumulations of vegetable matter, with stumps and roots of trees, firmly fixed in bluish clay, and evidently the remains of a forest which once grew on the spot, exist in all the inlets of Torbay. The most important and best known is that which, at very low water, is more or less exposed at Torre-Abbey sands . . . . . the greater part of which is commonly concealed by sand and shingle, but is occasionally laid bare by a heavy sea. In these and similar deposits of Goodrington and Broad Sands have been found the bones of various animals, among which are the red deer, the wild hog, the horse, the long-fronted ox, and the mammoth, the last, if not the last two, being certainly extinct."

The character of the evidence in favour of the mammoth having roamed the submerged forest of Torbay is well known. Many years ago some Brixham fishermen trawled a tooth of *Elephas primigenius* (which is now in the Museum of the Torquay Natural History Society) near the entrance of the bay, and neither Dr. Falconer, who identified it, Sir Charles Lyell, Mr. Godwin-Austen, nor Mr. Pengelly, who closely examined it, had any doubt that this molar is a true forest-fossil, which was torn by the trawl out of a submarine extension of the forest.

"It is probable therefore," continues Mr. Pengelly, "that the remains of the ancient forest occupy the greater part of the Torbay area. Nor is this merely a modern opinion, since Leland, in his 'Itinerary,' says 'Fisschar men hath divers tymes, taken up with theyr nettes yn *Torrebay* Musons of hartes, whereby men judge that yn tymes paste it hath been forest grounde.'"

From all which considerations, the author in question concludes:—

1. That the country must have been at least forty feet higher during the forest-era than at the present time; the depth of water in which the mammoth's molar was dislodged being from five to six fathoms.

2. That, subsequently to the forest-era, there was a general subsidence to the amount of forty, and perhaps of many more feet.

3. That the forest was of sufficient antiquity to have sheltered the mammoth and long-fronted ox.

* Trans. Dev. Assoc. vol. i. pt. iv. p. 30.

4. That the successive changes of level were, at least, tolerably uniform and were effected gradually.

The relics of man hitherto discovered in the submerged forest of Torbay are very few. They consist of two horns of red deer, found by Mr. Ardley in 1852, which exhibit undoubted marks of human workmanship, and of a single flint implement found by Mr. Watson, on Torre-Abbey sands, in 1883 *. Both of these finds have been fully described by Mr. Pengelly, and they sufficiently demonstrate that man must have witnessed that submergence of the forest area for which this author contends, while at the same time they raise the interesting question whether this submergence took place since or before the period of authentic history.

It has been considered a sufficient answer to say that Dr. Barham of Truro, in a paper read in 1825 †, has fully established the identity of St. Michael's Mount, near Penzance, with the Ictis of Diodorus Siculus, who, writing in the year 9 B.C., or nearly 2000 years ago, assigns to this island exactly the same level relatively to the sea as that which it has to-day. "Ictis" ‡, says Diodorus, "is left dry at low tides, at which times the inhabitants of Belerium, or Cornwall, transport thither, in carts, the tin which they produce on shore. Here the traders buy it from the natives and carry it to Gaul, over which it travels on horseback to the mouths of the Rhine."

Further reasons for believing in the persistence of the existing coast-levels through long periods of time are to be found in the fact that an embankment of Roman, if not of pre-Roman, age, situated in the Wash, stands upon the same horizon with a similar structure which has been built in its neighbourhood during modern times; while all the early English chroniclers, from Bede downwards, take their stand, so to speak, on the present levels of the country.

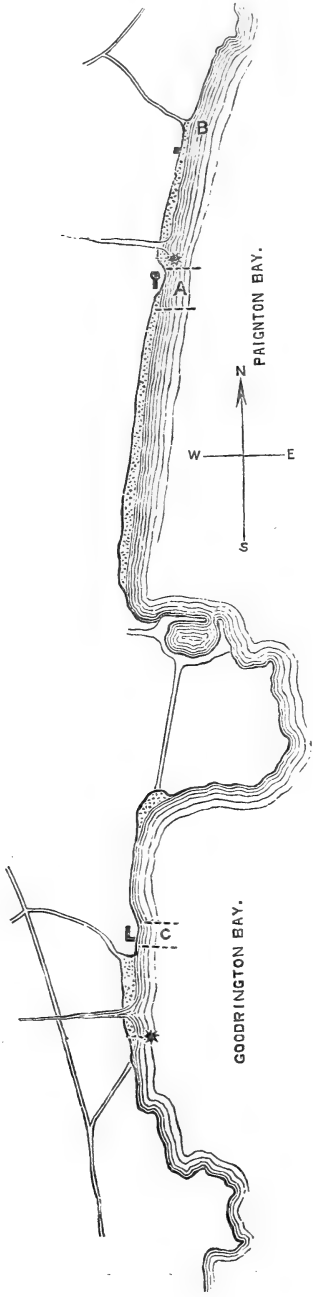
Mr. Pengelly's latest expression of opinion with regard to the age of the submerged forest of Torbay is as follows § :—

"It seems highly probable that the era of the forest growth was of great duration, extending from times before the extermination of the mammoth in Devon down to the introduction of the sheep and the goat. Be this as it may, while there are reasons for believing that the forests under consideration are more recent than the deposits which in the neighbouring [Kent's Hole and Brixham] caverns have yielded palæolithic tools interosculating with relics of several extinct mammalian species, there seems no reason, on the other hand, for doubting that they extend back to palæolithic times in Devonshire."

Such being the conclusions of the distinguished geologist who is, perhaps, better acquainted than any other investigator with the submerged forest of Torbay, attention will this evening be drawn to certain facts which seem to indicate that, while some of the so-called peat-beds of the forest are not older than Roman times,

* Trans. Dev. Assoc. vol. i. pt. iv. p. 36, and ibid. vol. xv. p. 137.
† Trans. Roy. Geol. Soc. of Cornwall, vol. iii. p. 86.
‡ Astronomy of the Ancients, p. 452.
§ Trans. Dev. Assoc. vol. xv. p. 138.

Fig. 1.—*Map of Paignton and Goodrington Bays.* (Scale 3 inches to 1 mile.)



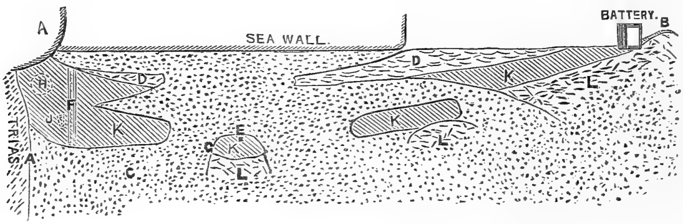
The stars indicate the spots where the finds have been made.

the clays in which the forest is rooted are either coeval with, or younger than, the bronze age in Britain.

The map, fig. 1, exhibits that part of Torbay which is occupied by Goodrington, Paignton, and Preston Sands, upon the first and last of which the finds which are about to be described were made. Referring, in the first place, to Preston Sands, these fringe a flat marshy valley, which, excavated in Triassic sandstones and conglomerates, and falling seaward with an extremely gentle slope, extends from Redcliffe Towers at A to Preston Lane at B (fig. 1).

The gales of December 1883 and February 1884 stripped nearly all the shingle off the upper half of the tidal strand between these two points, A & B, exposing the outcrops shown upon the plan, fig. 2. The forest-clay, K, was then seen to extend in a continuous

Fig. 2.—*Plan of Outcrops observed on Preston Sands* (A *to* B *on fig.* 1), *December* 1883 *to February* 1884. (Scale 340 feet to 1 inch.)



sheet of no great thickness from Redcliffe Towers to Preston Lane, while its seaward edge, instead of extending beyond low-water mark, as in the neighbouring inlets of Goodrington, Torre Abbey, Paignton, and Broad Sands, has been truncated by the action of the sea and is now confined to the limits shown upon the plan.

Inland the clay bed forms a flat basin, whose northern lip, rising with the flank of the valley, thins out to nothing at B, about seven feet above high-water mark, while its southern lip has been denuded, together with the Trias rock upon which it rests, to the level of the sea. Of the inland lip of this basin more hereafter.

The clay reposes directly upon the Trias at A (figs. 1 & 2), while, further north, it lies upon a somewhat remarkable breccia or "head" (L, fig. 2), which caps the Trias conformably from about the point C for a considerable distance northwards of Preston Lane. This breccia, which, together with the forest-clay underlying Preston Sands, has been minutely described by Mr. Pengelly*, consists of unstratified, angular, and loosely aggregated stones, packed, without order or arrangement, in a clayey matrix. The stones have nearly all been derived from a neighbouring hill of Devonian sandstone, whence

* Trans. Dev. Assoc. for 1878.

they have travelled to their present position along slopes which are, for the most part, so slight that it is difficult to suppose existing natural agencies to have been concerned in their transportation.

This breccia is, in all probability, an example of those deposits which, going by the name of "head" in the west of England, attain a great development in the maritime districts of Southern England and Northern France, and which Sir A. Ramsay and Prof. James Geikie have considered to be the equivalents of true glacial deposits, such as the till, but formed in districts which were not covered by the continental ice-sheets.

That the clay bed, which thus rests either upon the Trias rock or the breccia which caps it, forms the soil in which a portion of the submerged forest of Torbay is rooted, there is no sort of doubt. It is crowded with roots of all sizes; while here and there, the trunks of trees, whose roots branch through the clay in all directions, still stand erect and show themselves above the surface of the shingle whenever this is thinly strewn over the tidal strand. It is further covered, as shown on the map, with a mass of so-called peat, D (fig. 2), which is nearly three feet thick in some places.

Towards the end of December 1883, the sea exposed the area of clay and underlying "head" shown at E, fig. 2. E itself represents the trunk of a large tree about whose roots, which were partially denuded, the clay was several feet thick, and whence it thinned away to a feather-edge where it met the "head." Here, resting immediately upon the breccia at G, two pavement-like aggregations of stones were observed, each about two feet across, and of irregular outline, but both presenting the appearance of having once been united. These quasi floor-fragments consisted of well-rolled beach stones, the counterparts of certain trap pebbles, derived from the Trias, and very numerous on the present beach, but differing totally in character from the angular Devonian stones in the "head" on which they lay. That these were no heaps of pebbles shot down from a cart for some purpose, during a previous exposure of the breccia, as might well have seemed the case, was clear from the fact of their being everywhere interpenetrated by fibrils of the forest roots. A close examination revealed the curious fact that these trap pebbles were all cracked and traversed in every direction by minute fissures, so that the stones, usually difficult to break, even with a heavy hammer, could be pulled apart by hand. The fractures were of such a kind as forcibly to suggest that the stones had been heated; and some trap pebbles from the beach, upon being placed in the fire, soon exhibited similar fissures, and became cracked in exactly the same way as those forming the heaps in question. The interstices of the hearth, as the structure now began to be considered, were crowded with fragments of charcoal, easily distinguishable from the dark-coloured and decomposed vegetable matter furnished by the adherent rootlets.

But if the seeming floor were really a hearth, the question at once arose—Why should its builders have gone afield for materials when there was plenty of Devonian sandstones ready to hand in the

"head"? Why did they not light their fires upon it? On trial, however, it was found that such fragments of Devonian rock as the breccia contains fly to pieces with great violence on being heated, and were therefore quite unfit for the construction of fire-places. Finally, the floor-like structure, the heat-cracked stones, the presence of apparently true charcoal, and the proved unfitness of the breccia for hearth-building, suggested the conclusion that man had roamed in Torbay at some period subsequent to the deposition of the breccia capping the Trias, and prior to the deposition of the clay in which the submerged forest is rooted.

The discovery of a presumptive hearth raised hopes that some utensils of human origin might ultimately be found; nor was this anticipation disappointed. Towards the end of February 1884, a heavy gale bared the strand very widely, the junction of the forest-clay with the underlying Trias being well displayed at the point marked A in figs. 1 and 2. A large area was here uncovered, and the clay soon yielded several trap pebbles, cracked as if by fire, and fissured in exactly the same way as others which formed a part of the presumed hearth. This suggestive find was carefully followed up and the forest-clay thoroughly searched from A to B, after every tide, so long as the exposure lasted. The following articles were discovered, and are all exhibited on the table:—

1. An ingot of copper, found lying on the surface of the forest-clay. Although not actually imbedded, its position and appearance left no room to doubt that it had been disinterred by the last tide.

2. A portion of a similar ingot, also found lying on the surface of the clay, but having a few minute rootlets clinging to one of its crevices.

3. Numerous pieces of rude pottery, made of dark-coloured, unburned clay, mixed with small fragments of stone.

4. Three fragments of granite grinding-stones, originally of circular outline, and about ten inches in diameter.

5. A curiously shaped piece of whetstone.

6. A piece of glass.

7. A large number of angular stones consisting, according to assays made by Messrs. Henry Bath and Sons, the eminent tin- and copper-brokers of Swansea, of tin slags containing a small quantity of that metal.

8. A quantity of triturated tin-slag, without metallic contents.

9. A number of angular flints, among which are many having a decidedly artificial character.

10. Three or four flint implements, in some cases worn by use.

All these objects, with the exception of the copper, were actually disinterred from the clay, and were found either interpenetrated or embraced, according as they had or had not fissures, by fine rootlets, such as everywhere crowd the clay itself. Everything, except the whetstone and one flint implement, which occurred near Preston Lane, was found closely associated within the space of a few square yards, and at the spot marked H on the plan (fig. 2), or just where the forest-clay makes a junction with the Trias.

It is worthy of remark that the spot in question forms the natural point of discharge for water accumulating in the valley A B, and that water-rolled gravel occurs in the clay, quite close to the spot where the modern pipes F, which drain the low marshy land of the valley, have been laid down.

A word must now be said with regard to the position of these various articles vertically in the clay. This, together with the Trias ridge upon which it rests, has been greatly denuded within the limits of the tidal strand. A number of truncated posts were observed at J, and several of these were drawn. They consisted of tree-stems, four or five inches in diameter, and roughly pointed; but, in no case did more than five or six inches of their original length remain, proving that some feet of clay had been denuded since the posts were driven. The wood of these piles had its larger vessels threaded with the rootlets of other plants in exactly the same way as the forest-wood itself, which, whether prostrate or erect, is always interpenetrated by the roots of subsequent vegetation. The present tidal strand has therefore been a land surface since the posts were driven.

The Trias ridge upon which the forest-clay rests has been pared down *pari passu* with the latter, above which it projects only a few inches. The clay thickens rapidly from its junction with the Trias outwards, and is from three to four feet thick under the drain-pipes F. Assuming that the piles were originally driven not less than two feet into the clay, and bearing in mind that the objects on the table were found nearer the junction than the drain-pipes, it is probable that they occupied a position about midway between the original surface and the bottom of the clay bed at this point.

Reviewing the above facts, the conclusion seems inevitable that tin was smelted and bronze probably made on the spot in question at some time prior to the deposition of the forest-clays, and that the land surface supporting this early metallurgical establishment was the Trias rock. That the objects obtained from the clay were entombed during its deposition, is shown by the fact of their interpenetration by the rootlets for which that clay subsequently formed a soil; and, unless work was carried on within a pile-dwelling, the bronze-makers must have been antecedent in time to the forest-clay. If the platform of cracked stones found seated upon the "head" be accepted as the remains of a neighbouring smelting-hearth, then there is no question but that the suggested sequence of events is correct. Not only, then, was man living in Torbay at some period prior to the deposition of the forest-clays, but he was already acquainted with the art of smelting and a worker in copper and tin—facts which allow no escape from the conclusion that the soils in which the submerged forests of Torbay flourished were deposited since the beginning of the bronze age in Britain.

This, according to Dr. Evans, did not probably extend more than twelve or fourteen centuries backwards from the commencement of the Christian era, a period agreeing fairly well with M. Morlot's well-known estimates, which give 3800 years as the present age of

the bronze period in Europe. Sir John Lubbock has, indeed, advanced reasons for believing that the Phœnicians traded with Britain for tin fully 1500 years before our era; and, if this be so, we must suppose that the inhabitants of Belerium had been acquainted with the art of smelting for very many years before that date, there being nothing to suggest that the Britons were taught metallurgy by the Phœnicians. That the present coast-levels of England have persisted for at least two thousand years past seems to be fairly established; and, this being so, it follows that the subsidence, if subsidence it were, that placed the primitive smelting-works lying under Redcliffe Towers beneath the tidal waters of Torbay, must have occurred at some period prior to the Roman occupation, or during the 12, 15, or more centuries which, according to Dr. Evans, M. Morlot, or Sir John Lubbock, elapsed between the beginning of the bronze age in Britain and the coming of Julius Cæsar to our shores.

This question may be left for a moment in order to inquire how far a comparison of the objects found in the clay with other early works of human art supports the conclusion that the soils of the Torbay forest are of comparatively recent date. It will be observed that the fragments of pottery are similar in character to both British and Swiss lake-dwelling pottery, of which the former may be of any age from 1500 to 3000 years. The copper ingots have their exact counterparts in others now in the Natural-History Museum which were found in the black mould, or uppermost layer of Kent's Cavern; while whetstones and querns, similar to those taken from the clay, are not uncommon in Romano-British finds. Granting that the flint implement found by Mr. Watson, lying on Torre-Abbey sands, is a true forest-fossil, this in no way militates against the conclusion which is sought to be established. Not only have such tools been found associated with bronze implements in the Swiss lake-dwellings and elsewhere, but there is evidence of such association on the table this evening. The horn implement found by Mr. Ardley in the peat of the Torbay forest supports the ideas which have been advanced; for no one examining this tool with a critical eye can avoid coming to the conclusion that it has been shaped with something very much more effective for cutting-purposes than a stone hatchet.

It is well known that the Torbay forest is of later date than the cave-earth of the neighbouring Kent's Cavern, and later than some portions, at least, of its stalagmitic covering; for both these deposits contain the bones of certain extinct mammals whose remains are not found in the forest. The fauna of the latter is, indeed, the fauna of to-day, consisting for the most part of the red deer, the ox, hog, sheep, and goat, creatures whose bones are also found in the black mould of Kent's Cavern. There is some evidence, it is true, that the mammoth roamed in Torbay during the forest-era; but it is not conclusive, and it will be time to believe that *Elephas primigenius* was a contemporary of bronze-making man in Devonshire when its remains have been found in actual association with the works of the latter. This subject will be again referred to in the sequel; it is needful now to pass on to the description of

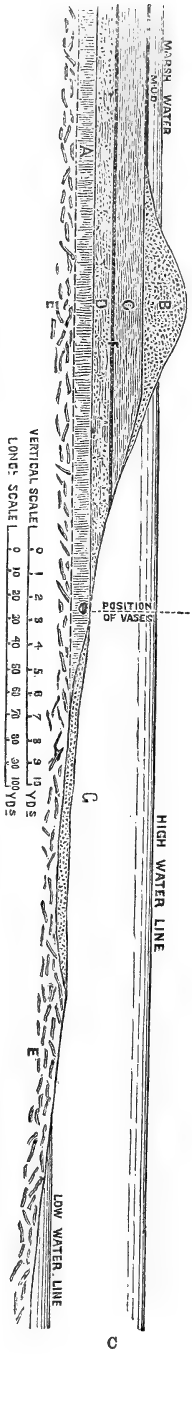
another find recently made by the writer's son on the tidal strand of Goodrington Bay (fig. 1).

This inlet has much the same general character as that which has already been described, and consists of wide and gently sloping sands, crowned with a prominent ridge of beach, behind which the ground is low, flat, and marshy, having been reclaimed from swampy conditions only in recent years.

Fig. 3 exhibits a section of the tidal strand taken through the spot where the "find" in question was made, and it will be observed that the forest-clay is here nowhere visible. At the bottom is a bed, E, consisting entirely of prostrate trees and vegetable débris; above that is another, A, composed of the stems of the water-bistort (*Polygonum amphibium*) standing as they grew; next, a stratum of silt and vegetable matter, D; then a thin layer of red clay, F, and lastly a bed of much-abraded reedy débris, C, upon which the beach, B, appears to rest. The thickness of the lowest bed is unknown, while that of the others is altogether about eight feet. Borings made by the Great Western Railway Company have shown that there are at least seventy, and it may be many more, feet of vegetable débris in the marsh immediately behind the beach, where it is crossed by the line carried on a high embankment.

On November 18th, 1883, the writer's son disinterred from the *Polygonum*-bed, A, fig. 3, two large pewter vases, one of which is now on the table, while the other has been presented to the Museum of the Torquay Natural History Society. These vessels

Fig. 3.—*Approximate Section of Goodrington Beach, showing undrained Marsh in rear, and position of Vases.*



A. Polygonum-bed. Stems upright.
B. Beach.
C. Débris of reedy matter.
D. Sand and vegetable matter.
E. Forest-bed, consisting chiefly of trees lying prostrate in all directions.
F. Red Clay.
G. Sand.

lay in contact, one above the other, were unmistakably imbedded, were full of fine vegetable débris, totally free from any admixture of marine deposits, and were crushed flat by long-continued gentle pressure. The metal of which they are composed has been found to consist of 10 parts of tin to 1 part of lead, and they have been pronounced by Mr. Franks of the British Museum to be almost certainly Roman. The bed in which they were found is about 10 feet below high-tide line, and vertically lower than the point at which the relics of bronze-making man were discovered in the clay bed of the adjoining inlet. This fact alone suggests the necessity of caution in coming to conclusions on the general question of subsidence.

Old maps of Torbay, such as those of Speed, dated 1610, Saxton, 1675, and Donne, 1765, demonstrate immense encroachments of the sea in this neighbourhood during comparatively recent times. The ordnance survey of 1809 shows that a road then traversed Goodrington Sands where the tide now flows; while the earlier surveyors whose names have been mentioned demonstrate a very considerable seaward prolongation of the land in Torbay within the last three centuries. There is little room to doubt that the Roman vases in question were lost in Goodrington Marsh at a time when the beach which dammed its waters was far seaward of its present position and of the spot where the vessels were found. Since that time, the beach, receding before the advancing sea, has passed over the vases, which the waves have, finally, disinterred from the foreshore.

The vertical position of the vessels, 10 feet below high-water mark, may be explained by supposing that the fallen trees and vegetable detritus, filling the Goodrington valley to a depth of at least 70 feet, formed a very compressible mass, and as this became gradually consolidated, the reedy beds growing above the prostrate forest gradually settled and carried any enclosed objects down with them.

The same bed of clay which underlies the forest on Preston Sands, is also present at the same levels at Goodrington, where, however, it is generally covered with sand and shingle. In the centre of the bay there occurs a reef of Devonian shale, C, fig. 1, which is covered at high, and exposed at low water. Upon either side of this reef the clay reposes, just as it does upon the Trias reef immediately below Redcliffe Towers in the neighbouring bay. Thence it dips rapidly on either hand, and is soon covered with a thick layer of peaty matter, as is also the case on Preston Sands. There is, however, nothing to show whether this bed of clay passes continuously from the reef under the great depth of forest-deposits which the Great-Western borings have shown to exist at the lowest part of the Goodrington valley.

With regard to the character of the forest-clays Mr. Godwin-Austen*, writing in 1842, says that the submerged forest of Torbay rests on lacustrine mud, which at Broad Sands contains shells of *Paludina impura* in great abundance; while at Goodrington also

* Trans. Geol. Soc. ser. 2, vol. vi.

there are traces of lacustrine marl. The writer, on the other hand, while totally failing to find any freshwater shells in either of the inlets, has met with *Scrobicularia*, *Hydrobia*, *Littorina*, and *Melampus*, the three former abundantly, in a single but very limited exposure of the clay only a few hundred yards south of Redcliffe Towers. Of these shells, the *Hydrobiæ* formed a bed several inches in thickness, and would have given the idea of their having lived and died during the accumulation of the clay, but for the fact that they occur at precisely the same horizon as living shells of the same species would do. It is quite impossible to suppose that an estuarine bed of clay which has been elevated to form the soil of a forest should, upon subsequent subsidence, sink to exactly the same horizon as it occupied before its elevation; and it is probable, therefore, that the marine shells in question flourished where they were found during some recent but prolonged exposure of the clay, while the shifting of derived mud during that time might give them the appearance of being bedded. The clay itself, when not charged with vegetable matter (which gives it a blue tinge), or stained at its margins by the red rocks upon which it lies, is almost white and of an extremely fine, butter-like consistency. To this excessive fineness must probably be attributed the fact that the clay is white, while the surrounding drainage-area is composed chiefly of red rocks. Not the slighest evidence of marine action is exhibited by the lip which, as already stated, can be traced around portions of the shallow basin in which the clay accumulated; and, in view of this fact, of Mr. Godwin-Austen's positive observation, and of the possibility of explaining away the rare presence of marine shells in the deposit, it is probable that the clay is of lacustrine origin.

It is time to consider the question of the supposed subsidence of the area under consideration in the light of the following facts:—

1st. That the forest-clay of Preston Sands contains relics of bronze-making man.

2nd. That the upper, peaty beds of the submerged forest of Goodrington have yielded Roman remains.

It has been suggested that the shores of Britain have probably remained at their present levels for at least 2000 years past; and if Dr. Evans', M. Morlot's, and Sir John Lubbock's views may be relied upon, the bronze age in Britain is not older than 4000 years. But if, as Mr. Pengelly suggests, Torbay stood at least forty feet higher than now during the forest-era, it becomes necessary to believe that, at some time within the twenty centuries preceding Roman times in Britain, the Trias rocks of Preston Sands have been:—

1. Submerged for the deposition of the forest-clay.
2. Elevated to a height of at least 40 feet.
3. Depressed to their present level.

That a coast which has remained stationary for the last 2000 years should have made such active use of the preceding twelve or twenty centuries for the purposes of oscillation, is rather hard of belief. Either the bronze age must be of unsuspected antiquity, or the

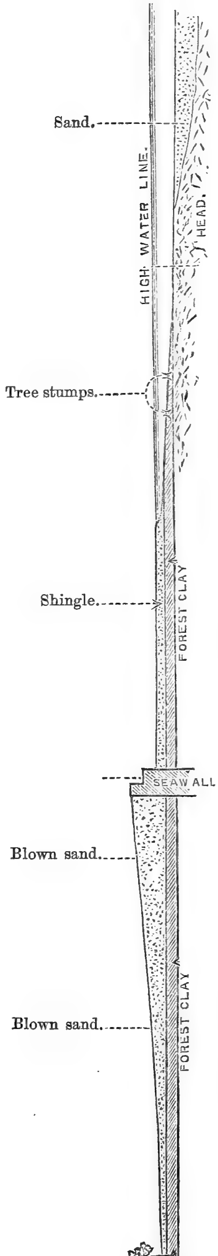


Fig. 4.—*Section of the Exposure at Redcliffe Towers, April 22, 1884.* (Scale 60 feet to 1 inch.)

objects to which attention has been directed this evening must have been lodged where they were found while the land stood at existing levels.

In attempting to answer this question attention will be strictly confined to the Paignton-Preston inlet, a section of which is shown in fig. 4. The clay-bed is here only just below high-water mark at that part of the marshy land most remote from the sea. It passes seaward with a very slight inclination to at least 750 feet from the shore, that being the length of the Paignton Pier, whose piles were all screwed into the clay. It is covered, inland, first with coarse sand, among which are found many large cockle-shells and occasional patches of shingle; while, over all, is a layer of blown sand, the surface of which is some two feet above high-water mark. Its seaward margin, being unprotected by a beach, is in course of truncation and destruction by the waves; but behind the beach such plants as the water-bistort (*Polygonum*) are growing luxuriantly, while willows are extensively cultivated in the swampy soil. It is noteworthy that most of the trees found prostrate in the forest-clay are also willows.

The basin in which the clay lies has a lip which is distinctly visible in the cliff near Preston Lane, and whose position on the slopes of the neighbouring hills is well known to the village builders. This stands about seven feet above high-water mark, and its margin (as already mentioned) gives no evidence of having ever been fringed by a marine beach, while the extreme fineness of the clay itself attests its deposition in still and scarcely turbid waters.

The evidence in favour of extensive encroachment of the sea in Torbay is conclusive. Large tracts of land, houses, and roads have disappeared within the memory of man; while maps less than 300 years old show, with more or less accuracy, a shore-line hundreds of feet in advance of the present one. It seems probable therefore that the Paignton-Preston inlet was once barred by a beach, distant at least 750, and probably very many more, feet from the present beach, behind which the land-water accumulated to a height of about seven feet above the high-tide level, and that in the lake, or mere, thus formed the forest-clay was laid down. By the breaking down of the dam, the sea was admitted, covering what is now Paignton Marsh with coarse sand, to be followed by blown-sand deposits, and in this way the sea was again expelled to the limits of the present coast-line. Meanwhile the willows and marsh-plants whose débris and roots form the greater part of the so-called peat-beds overlying the clay took possession of the low-lying ground.

Man, as we have seen, was present in the Paignton-Preston inlet either before the lake in question was formed, living on the "head," or inhabiting a pile-dwelling during the deposition of the clay, or even, if the lacustrine conditions were intermittent, settled on the clay itself; but, in any case, the suggested explanation makes it unnecessary to suppose that the bronze-makers of Redcliffe Towers were witnesses of those wide oscillations of level which have heretofore been associated with the physical history of the submerged Torbay forests. The topmost beds of these deposits have been shown to be no older than the Roman occupation of Britain, while their base dates from the bronze age. If the molar of *Elephas primigenius* which has already been referred to was really derived from a seaward extension of the forest lying exposed between tide-marks in Torbay, then it must be concluded that the mammoth survived in Devonshire almost down to Roman times, and that he was certainly contemporary there with bronze-making man.

But it is not necessary to suppose that the same bed of clay and the same forest were continuous for great distances seaward in Torbay. Buried forests are, elsewhere, almost always found in tiers, sometimes, as in the Fenland districts, four or more one above another. At Blackpool, only a few miles from Torbay, Mr. A. R. Hunt* has given reasons for believing that one submerged forest rests upon another; and these forests might, of course, differ vastly in age. Similarly there may be forest-beds beneath the waters of Torbay older than those which are visible on Torre-Abbey, Paignton, Preston, and Goodrington Sands, and the mammoth's tooth may have come from one of these. In any case, the submerged Forest of Torbay, and possibly therefore other submerged forests fringing the English coast, are even more truly things of yesterday than has hitherto been supposed.

* Trans. Dev. Assoc., A. R. Hunt, July 1881.

Discussion.

Dr. H. Woodward said that it was interesting to find that the copper ingots exhibited by the author closely resembled ingots of the same metal obtained by Mr. Pengelly from Kent's Cavern. The pottery from the two localities was also similar.

Prof. T. Rupert Jones doubted the palæolithic age of the flint-flakes. Similar flakes have been found on the surface in many parts of southern England, and are by no means of palæolithic age.

Prof. T. M'K. Hughes said that one of the most interesting points connected with the paper was the explanation of a "submerged forest" without the necessity for any submergence. He quite agreed with the author that the damming back of the sea and the growth of trees below high-water mark behind the dam, furnished a probable explanation of the phenomena. The occurrence of the two clays described might indicate two different periods, and submergence might have occurred between them. The evidence of the chips was not of much value, as they might be of any age. The pottery appeared to be British.

Mr. Blanford agreed with the author in his main views, but wished to point out one difficulty. The supposed tin-smelting hearths were some 10 feet below high-water mark, and the ground must have been too wet for smelting, if not actually below water.

Mr. Topley expressed his general agreement with the author; but remarked that similar opinions, as to the recession of shingle-beaches and the formation of "submerged forests" without subsidence, had been put forward by Mr. Yates, Col. Greenwood, and others. Where the forest-growth, however, extended to or below low-water mark, he thought subsidence must have occurred.

The Author thanked Dr. Woodward for his remarks, and for the access he had given him to similar ingots in the Natural History Museum. He had used the term "palæolithic" merely to indicate the type of the flint fragments. He stated that his paper answered Mr. Pengelly, who thought that there had been a submergence of 40 feet. With regard to the hearth he admitted the difficulty pointed out by Mr. Blanford, for there was no doubt that this was resting on head.

3. *The* Cretaceous Beds *at* Black Ven, *near* Lyme Regis, *with some* supplementary Remarks *on the* Blackdown Beds. By Rev. W. Downes, F.G.S. (Read November 5, 1884.)

Four visits, each of three or four hours' duration, to the same section and upon almost consecutive days ought to afford the opportunity for recording somewhat, unless the section be either one that is void of interest, or already so worked-out as to leave nothing further to be recorded. In the present case, when among the previous workers are found the names of Etheridge, Meyer, De Rance, Price, and others, it may seem probable that the subject might have been exhausted. As, however, the writer's experiences do not quite agree with all that has before been written, and as he found not a few fossils in a bed hitherto (as he believes) supposed to be non-fossiliferous, a brief memoir may be of service.

The section in question is about halfway between Lyme Regis and Charmouth, in the sea-cliff. Four years ago there had been a landslip there, which necessitated a reconstruction of the high road. According to a local informant this landslip revealed for the first time the presence of a bed of Gault; but this statement was certainly erroneous, for fossils from the Gault bed seem to have been in the Jermyn-Street cases long ere that date. But the landslip seems to have done some service to geology in making the Gault bed in one place more accessible, and in causing a new and clean-cut section of the beds above it to be made in the course of the reconstruction of the road.

The whole cliff-section may be roughly computed to be 300 ft., of which the lower 200 ft. is Lias, and the upper 100 ft. is Cretaceous. The latter may be subdivided again, as 25 ft. of black loamy clay at the base, and above it 75 ft. of yellow non-calcareous sand, with a capping of chert gravel. Further westward the Greensand is calcareous, but not at this spot. The Gault is of very much the same colour as the Lias beneath; but as the former is pervious, and the latter impervious, it appeared to be more easy to trace the boundary with the eye than to traverse it with the feet; for in the few places where a ledge is accessible there is a quagmire of black slush, the result of the outbreak of springs.

Mr. De Rance, as quoted by Mr. Price ('The Gault' &c. p. 27), tells us that, "at Black Ven, where it (*i. e.* the Gault) is best seen, it is divided from the Cowstones above by a few feet of yellow sand. A comparison of the fossils from this place with those at Folkestone tends to correlate the Dorsetshire Gault with the Lower Gault of Folkestone, rather than with the Upper Gault; in which case, supposing the Whetstones in the Blackdown beds to represent the Cowstones, they and other portions of the former may be equivalents, in time, of the Upper Gault."

It is with reference to the above questions that the following observations are especially made. The fossils found in the Gault by the writer were 33 in number, and in the following proportions:—

Lima parallela	10
Inoceramus concentricus	6
Thracia ?, sp.	1
Modiola ?, sp.	1
Pinna tetragona	3
Venus ?, sp.	2
Cucullæa carinata ?	3
Panopæa?	1
Turritella granulata ?	4
Hemiaster ?, sp. (crushed specimens)	2
	33

The chief point to be observed with regard to this list is the great preponderance of *Lima parallela*, a form unknown in the Blackdown beds. *Inoceramus concentricus*, which comes next in point of numbers, is useless for marking an horizon, as it occurs everywhere in Cretaceous beds. Negatively the absence of *Belemnites* and of *Inoceramus sulcatus* is noticeable in comparing this bed with that at Folkestone. Of *Ammonites*, I believe that *A. splendens* is the only form hitherto found.

This black bed passes upwards into yellow sand of the ordinary Greensand type. No fossils from the latter have, so far as I am aware, been yet recorded. I searched long without finding any. After a while, however, a careful examination of the roadside section revealed the fact that organic remains had been abundant there, though the traces of them had in the large majority of cases been obliterated. In some cases a spiral univalve, *e. g.*, would be traceable only by a spiral line of discoloration, which fell to pieces on being touched with the penknife. Elsewhere, by very carefully removing the sand, many casts of bivalves were found. The sand was, however, not cemented in any way. It was simply balled together like a snowball, and fell to pieces with any but the most tender handling. Of course very few of such casts could be identified. Indeed, the only form of which I felt really sure was *Cyprina cuneata*, which seemed to be abundant. The search was, however, fascinating, and it led me at last to the discovery of a nest of fragmentary fossils silicified, and altogether resembling very poor Blackdown specimens. The nest was a roughly spherical patch in the sand, about 1 ft. in diameter, the matrix being rather darker and more ferruginous than the rest. Its origin appeared to be a chemical superinduced change around a nucleus of some kind. In this little spot I found evidence, mostly fragmentary, of the following forms:—

Cyprina cuneata (abundant).		*Cardium proboscideum* (3 small fragments).	
Gervillia rostrata (abundant).		*Pecten orbicularis?*	1
Cytheræa caperata	4	*P. quinquecostatus*......(fragment)	1
Trigonia scabricula	2	*Turritella granulata*	1
Cucullæa glabra	4	*Phasianella?*, sp.	1
C. fibrosa	1	*Serpula.*	
Exogyra	1	*Siphonia?*	

The spot in which these occurred was about 50 ft. above the spot in the Gault where I obtained the other fossils, and in nearly a straight vertical line above it. All my subsequent endeavours to find another such nest of fossil remains proved futile; but its occurrence is a remarkable comment upon the fragmentary character of geological evidence. But for this little local alteration of the matrix, affording conditions for preservation, and proving that it had once been teeming with life, the rock might have been pronounced altogether barren of organic remains.

In this spot, then, 50 ft. apart vertically, are two very distinct horizons. There is but one (possibly not even one) specific form in common. That one would be *Turritella granulata*; but the specimen from the Gault-bed is too poor a one for exact determination. The fauna of the upper bed is a much nearer approach to the Blackdown fauna than that of the lower, and for this reason as well as from its position, is probably its equivalent; but the absence of some of the commonest Blackdown forms is noticeable. Among the commonest Blackdown forms is *Pectunculus umbonatus*, and the closely allied form *P. sublævis*; these, however, at Blackdown are distinctive of rather high horizons. One might therefore be justified in reasoning from this fact that the upper Black-Ven bed might be the equivalent of the lower Blackdown. But *per contra* in the Black-Ven bed we have a great preponderance of *Cyprina cuneata*, which at Blackdown is distinctive of a bed intermediate between the two *Pectunculus*-beds.

The evidence, so far as it goes, seems to show alternation of specific horizons. It would seem as if inosculations due to changing littoral conditions occurred among the beds, as before suggested by Prof. Seeley *, with certainly a general thinning-out to the westward. Under such circumstances it is questionable if we shall ever be able to subdivide the Cretaceous beds of the West of England into the marked divisions of Gault and Upper Greensand which are applicable to the beds to the eastward. The black *Lima-parallela* bed of Black Ven is, however, clearly of lower horizon than the lowest of the Blackdown beds; for it thins out before reaching Sidmouth, and apparently immediately underlies the Blackdown series. The general thinning-out to the westward is very evident. Mr. Hudleston has pointed out that the Lower Greensand has thinned out eastward of the vale of Wardour, though, according to Mr. Etheridge, there are some traces of it to be found in the more southerly beds at Black Ven †. The Gault, as shown in the coast-section, evidently

* Quart. Journ. Geol. Soc. vol. xxxviii. (1882), p. 92.

† Ibid. p. 93.

thins out to the eastward of Sidmouth; and my own investigations at Blackdown and Haldon will, I think, prove that at least the lower two thirds of the Blackdown series have thinned out in the hiatus which separates Blackdown from Haldon.

I will here take the opportunity of saying, as germane to the present subject, that I have a few additions to make to the list of Blackdown and Haldon fossils published in the Quarterly Journal of 1882.

In that list, under the head "Actinozoa," appears "* *Smilotrochus Austeni* (E. & H.) [? *Trochosmilia*] T. C." As regards the Blackdown form, I believe it ought to have been written "*Trochosmilia tuberosa* (Ed. & H.) T. C. D."; but the specimens are not good, and Prof. Duncan, to whom I showed them, would not be responsible for their nomenclature. This species, or one closely approaching it, is less uncommon at Blackdown than has been supposed; but it comes from an horizon far removed from that of the Haldon corals, and therefore should not be confused with them. I obtained five specimens from bed 3 (see tabular view, Quart. Journ. Geol. Soc. Feb. 1882, p. 84), whereas the Haldon corals, mostly compound forms, are found in bed 13.

After *Inoceramus sulcatus*, as Mr. Meyer has pointed out to me, ought to be added *I. semisulcatus*.

Nucula pectinata, Sow., ? variety. This species is referred to Blackdown in Morris's Catalogue; but the actual specimen appeared to have vanished from all known collections. I therefore omitted this species in my list; but I have since found it. Mr. J. S. Gardner considers that my specimen more resembles those from the Chalk Marl than those from the Gault.

Solarium, clearly allied to *S. ornatum*, but (as Mr. J. S. Gardner has pointed out) differing from Folkestone specimens "*in the absence of the distinct row of ribs which extend about halfway across the upper part of the whorl.*" The same correspondent informs me that my specimens very closely approach a form from the Grey Chalk.

In the list of Haldon corals (p. 91) two of the commonest forms have somehow been omitted. I allude to *Astrocœnia decaphylla* (Ed. & H.) and *Isastræa haldonensis* (Duncan).

"*Orbitolina*-chert" (bed 15). This, I am now inclined to think, is no distinct bed, but merely a local variation from an ordinary chert bed.

I have also to add, from bed 13 at Haldon, *Elasmostoma Normanianum*, of D'Orbigny. I am told by Dr. Hinde that this is one of the calcareous sponges, since silicified, and that this species also occurs at Warminster, and in the Tourtia at Essen-an-der-Ruhr.

Discussion.

Mr. Etheridge generally confirmed the correctness of Mr. Downes's section. He stated that a bed of "Carstone," from 1 to 2 ft. thick, rests on the Lias of Black Ven.

Mr. Meyer stated that he had not been so fortunate in his visits to Black Ven as to find the bottom beds of the Cretaceous uncovered; nor had he succeeded in finding fossils in the sand above the Gault. He agreed with Mr. Downes that the Blackdown beds represent the whole or part of the Gault. He himself had thought at one time that the Blackdown beds might represent the Gault and Lower Greensand; but he had now been led to conclude that the supposed Lower-Greensand fossils from Blackdown were really of different species.

The Author was inclnied to regard the Blackdown beds as being rather Upper Greensand than Gault; but he did not think the distinction of Gault and Upper Greensand could be made out in the western extension of those Cretaceous deposits. The term "Gault" had been used in the paper to signify the black argillaceous bed, and not as a time-limit. There were certainly many Gault forms in the Blackdown beds.

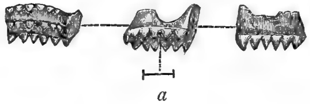
4. *Note on the* RESEMBLANCE *of the* UPPER MOLAR TEETH *of an* EOCENE MAMMAL (NEOPLAGIAULAX, *Lemoine*) *to those of* TRITYLODON. By Sir RICHARD OWEN, K.C.B., F.R.S., F.G.S., &c. (Read November 19, 1884.)

SHORTLY after the communication to the Geological Society of the paper on *Tritylodon* * I was favoured by the author, Prof. Lemoine, with a copy of his 'Mémoire,' "Etude sur le *Neoplagiaulax* de la Faune Inférieure des Environs de Reims" †. The chief interest of that 'Mémoire' was, to me, the dental characters of the small mammal there discovered, especially those of the upper molar teeth; while the general characters of the dentition, by their resemblance to those of the Mesozoic *Plagiaulax*, are also notably suggestive ‡.

With a premolar, in relative size, shape, and sculpturing of crown, so closely repeating the peculiarities of that tooth in our Oolitic marsupial as to have suggested the generic name of the lower Eocene mammal of Reims (*Neoplagiaulax*), were associated true molars more nearly resembling, in those of the upper jaw, the corresponding teeth of *Tritylodon* than did the teeth of the genera *Microlestes* and *Stereognathus* with which I compared them §.

Figs. 1–3.—*Upper Molars of* Neoplagiaulax eocænus, *Lemoine, after Lemoine, Bull. Soc. Géol. Fr. sér.* 3, *tom.* xi. *pl.* vi. *figs.* 17 *u*, 17 *l*, *&* 17 *e*.

Fig. 1. Fig. 2. Fig. 3.



1. From beneath. 2 & 3. From the sides. *a*. Natural size.

The figures 17 *u*, 17 *l*, 17 *e*, pl. vi, of M. Lemoine's 'Mémoire' appended to the present note, will enable the resemblance of the upper molars of *Neoplagiaulax eocænus* to those of *Tritylodon* to be appreciated. In size the difference is almost as great as that shown by the molars of *Microlestes* ‖. And here I may observe that, as the lower molars of *Neoplagiaulax* have only two longitudinal series of tubercles, it suggests a surmise that the lower molars of *Tritylodon* may be found to present the same less complex character as com-

* Quart. Journ. Geol. Soc. Feb. 1884, vol. xl. p. 246, pl. vi.

† Bulletin de la Société Géologique de France, 3e série, t. xi. p. 249.

‡ Compare "pl. v. figs. 1–3," with figs. 9 and 16, pl. iv. of my "Extinct Marsupials of England," pp. 75–87, in the 'Extinct Mammals of Australia,' 4to, 1877, p. 75.

§ *Loc. cit* pp. 150, 151.

‖ *Loc. cit.* pl. vi. figs. 8–10 (magn. 3 diameters).

pared with the upper ones; and, at the same time, that the rare detached molars on which the genus *Microlestes* is founded may be also those of the lower jaw.

I add the following paragraph from the close description by Prof. Lemoine of the upper true molars of his rare and interesting fossil:—

"*Molaires supérieures* (pl. vi. 17–17 *bis*) présentent trois rangées de denticules bien caractéristiques."—"La rangée médiane de denticules se trouve séparée des deux rangées latérales par un sillon assez large. Les rangées latérales de denticules bordent de chaque côté la couronne ; les denticules en question sont de même forme que les denticules médians, mais ils sont plus petits. Nous avons compté cinq denticules pour chacune de ces rangées" (*loc. cit.* p. 260).

Here is indicated the chief difference, besides size, between the upper true molars of *Neoplagiaulax* and *Tritylodon*. In the latter the tubercles ("denticules") do not exceed three in number in the middle row and the inner row, and are but two in the outer row: and they are of proportionally larger size.

Discussion.

The President expressed his regret and that of the Society that the care which the author's health now required prevented him at this season of the year from being present at the reading of the paper.

Prof. Seeley referred to the discovery by Dr. Fraas of teeth of the Trias of Wurtemberg, to which he gave the name of *Triglyphus*. Prof. Neumayr of Vienna had lately pointed out the resemblance between the teeth of *Tritylodon* and *Triglyphus*. He could not agree with the author in thinking there was any evidence that the molars of the lower jaw had only two rows of tubercles.

Mr. Lydekker also doubted the truth of the author's suggestion concerning the teeth of the lower jaw. He thought that the condition of the teeth in the upper jaw of *Tritylodon*, the fourth molar being less worn than the fifth, pointed to the conclusion that this form belonged to the Marsupialia rather than to the Eutheria.

5. *On the* Discovery *in one of the* Bone-caves *of* Creswell Crags *of a portion of the* Upper Jaw *of* Elephas primigenius, *containing* in situ *the first and second* Milk-molars (*right side*). By A. T. Metcalfe, Esq., F.G.S. (Read November 19, 1884.)

[Abridged.]

I desire to bring under the notice of the Society a portion of the upper jaw of *Elephas primigenius*, containing *in situ* the first and second milk-molars, discovered by myself in one of the bone-caves of Creswell Crags.

It will be remembered that these caves have, during the last ten years, through the exertions of the Rev. J. M. Mello, F.G.S., been systematically explored under the auspices of a committee of the British Association, and that papers describing the caves and giving the results of the explorations have appeared in the Society's Journal. The specimen now on the table was obtained by me *prior* to these explorations. In securing it, therefore, I in no way interfered with any authorized investigations; for none had then been set on foot. I found the specimen in the red sand or cave-earth of the "Pin-hole Cave," and quite at its entrance. This cave is the most westerly on the north or Derbyshire side of the ravine, and has been fully described by Mr. Mello, who gives the following section of its beds (Quart. Journ. Geol. Soc. vol. xxxi. p. 681):—

1. Surface-soil, containing recent pottery, bones &c., 1–6 inches.
2. Damp red sand, with rough blocks of magnesian limestone, quartz, quartzite, and other pebbles, and numerous bones, 3 feet.
3. Lighter-coloured sand, consolidated by infiltration of lime. No bones (?).

Sir Richard Owen has very kindly undertaken to describe my specimen. He informed me some time ago that the National Collection had evidences of all the phases of dentition of the mammoth except the earliest, which is exemplified in the small anterior tooth in the portion of jaw discovered by me, and that the true value of my specimen would be its *completion* of the series now arranged for public instruction in the British Museum. I naturally feel that a suggestion from such a high quarter cannot be disregarded, and, in accordance therewith, I have undertaken to present the specimen to the British Museum.

6. NOTES *on* REMAINS *of* ELEPHAS PRIMIGENIUS *from one of the* CRESWELL BONE-CAVES. By Sir RICHARD OWEN, K.C.B., F.R.S., F.G.S., &c. (Read November 19, 1884.)

CUVIER, in his chapter "Sur les Eléphans Fossiles"*, notices a fossil molar tooth discovered at Fouvent as having come from a very young individual and as being "une vraie molaire du lait;" a figure of the grinding-surface is given, of the natural size, in pl. xii. fig. 2. The antero-posterior extent of that surface is 22 millim., the extreme transverse extent is 13 millim.

The difference of size between the tooth figured by Cuvier and that preserved in the jaw in Mr. Metcalfe's specimen is such as to suggest one of specific value; but the greater degree of wear to which the Cresswell-cave fossil has been subject, during life, and the inability to compare it with the original of the figure above cited, prevents such conclusion. The second detached molar figured by Cuvier, and noted as a "second molar of a young mammoth," shows no such increase of size: it is stated to have been derived from the environs of Toulouse.

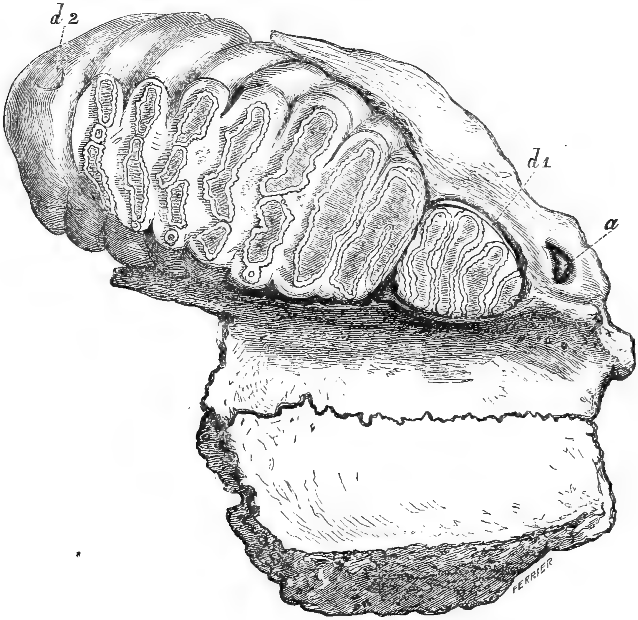
Subsequent figures and indications of the first and second molars ascribed to *Elephas primigenius* represent, like Cuvier's, detached teeth or tooth-crowns, leaving it undetermined whether they be from the upper or the lower jaw.

In the account of the succession of the molar teeth of the existing Indian Elephant, the first molar, upper jaw, has a crown 20 millim. in antero-posterior diameter, 13 millim. transversely; the crown consists of four principal plates and a fifth smaller one, or "talon" †. That the *Elephas primigenius* had a similar first grinder of the series was indicated by the socket in the lower jaw, from brick-earth at Ilford, Essex ‡. A reduced view is given of the crown of the second molar, lower jaw, from Kent's Hole, showing eight transverse plates and a talon §.

The specimen which Mr. Metcalfe has kindly submitted to me (figs. 1 & 2) is the first I have seen which demonstrates the characters of the first and second upper molars *in situ*. It is a portion of the fore part of the maxilla, showing the bony palate, with those teeth of the right side; the corresponding sockets and teeth of the left side are broken away. The two molars have a longitudinal extent of three inches and one line (=78 millim.). The worn surface of the foremost has a length of 14 millim.; that of the second molar of 50 millim.; but the entire length (fore and aft) of this tooth is $2\frac{1}{2}$ inches (=62 millim.), the two hindmost divisions of the tooth not having risen into use.

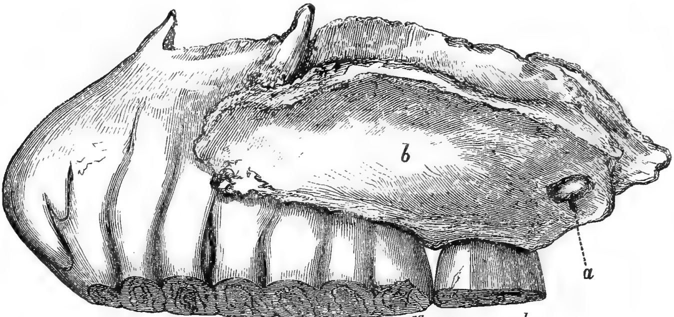
* Recherches sur les Ossemens Fossiles, ed. 8vo, 1834, tome ii. p. 175.
† Odontography, 4to, 1845, p. 632, pl. 148, fig. 2.
‡ British Fossil Mammals, p. 223.
§ Ib. p. 224, fig. 87.

Fig. 1.—*Under or palatal view of a portion of the forepart of the Maxillary Bones of* Elephas primigenius, *with the Grinders of the right side.* (Natural size.)



d_1, d_2. First and second grinders. *a.* Worn root of first grinder.

Fig. 2.—*Outer side view of a portion of the Right Maxillary, with the first and second Grinders of* Elephas primigenius. (Natural size.)



a. Worn root of first grinder. d_1, d_2. Grinders.

The worn, flat, and smooth surface of the first molar in annexed sketch (Fig. 1, d_1) shows the foremost plate almost worn away; the second plate retains a feeble indication of two of its mammilloid prominences; the third and fourth plates have, each, indications of four such prominences; but their grinding-surface has been worn down to a hind "talon," which had just come into use. The original unworn or little-worn surface of this molar would have nearly the size of the tooth from Fouvent, and indicates that to have come from the upper jaw. The roots of the more worn molar in the Cresswell specimen are fully developed: the anterior one (Fig. 2, *a*) extends in a forward curve, with its closed end 13 millim. in advance of the part of the crown it supports. The crown has been worn down to a subtriangular figure with the apex forward; the breadth of the grinding-surface near the base is 15 millim. The greatest breadth of the second molar (d_2) where the hinder root begins is $1\frac{1}{4}$ inch (=32 millim.). Of this tooth, the fractured surface of the right maxillary exposes three roots, the first and second diminishing to their almost closed ends; the common, widely open pulp-cavity of the hinder root is also exposed; its subsequent division into an outer and inner fang is indicated.

The specific distinction from *Elephas indicus* is shown, in the present portion of *Elephas primigenius*, by the greater relative breadth of the second molar, especially towards the base of the crown.

The thickness of the constituent enamel-clad plates is but little less in proportion to the mass of the crown than in the larger variety ("Dauntelah" of Corse) of *Elephas indicus*. But these plates show their specific proportions in a more marked degree as the subsequent progressively larger molars are acquired.

The portion of the bony palate owes its transverse concavity chiefly to the development of the inner wall of the molar sockets. The broken surface above that plate gives indications of pneumatic cavities.

In contemplating this rare relic I have not been able to suppress sympathy with the unhappy juvenile British elephant, which, long ages ago, fell a prey to some dire contemporary spelæan carnivore, by whose jaws the immature skull has been reduced to fragments.

Discussion.

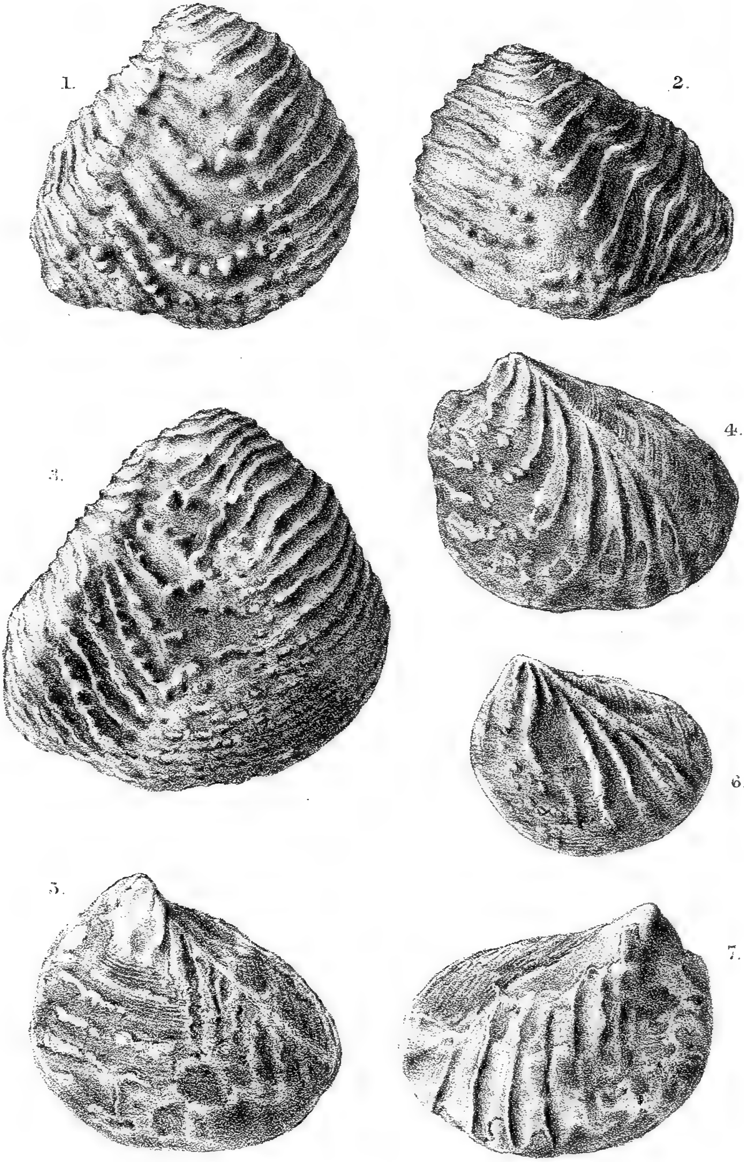
Mr. Lydekker said that there was some ambiguity about the terms first and second milk-molars; they are better termed antepenultimate and penultimate. There may be another anterior milk-tooth abnormally developed, and one specimen of the African Elephant in the British Museum apparently contains this tooth. The specimen now exhibited and described is not, however, the only one with the milk-molars *in situ*; there is another in the Bright collection from the opposite side of the upper jaw, but from an unknown locality.

Prof. SEELEY stated that a specimen of the full first dentition of *Elephas primigenius*, comprising the teeth of both upper and lower jaws, found in the gravels of Barnwell near Cambridge, was formerly in the Woodwardian Museum. It was lent to the late Dr. Falconer, and after his lamented decease it could not be found.

Dr. H. WOODWARD stated that a specimen of *Elephas antiquus*, with milk-molars *in situ*, existed in the Museum of Practical Geology. He was not quite certain whether the specimen on the table did not belong to the same species. The specimen in the Bright collection is also labelled *E. antiquus*. Young teeth of *E. primigenius* have been found in abundance at Ilford and elsewhere in the Thames valley, all proving that the animal was indigenous in Britain. The specimen exhibited was of great interest as its exact locality was known.

Mr. E. T. NEWTON remarked that the specimen in the Museum of Practical Geology was similar to that on the table, but it was very difficult to distinguish between the young molars of the two species referred to without careful comparison.

Mr. METCALFE expressed his thanks to Sir Richard Owen for his kindness in describing the specimen, and to the Fellows of the Society for the manner in which they had received this communication.



A. S. Foord del et lith.

Mintern Bros. imp.

TRIGONIÆ.

7. *On the* Stratigraphical Positions *of the* Trigoniæ *of the* Lower *and* Middle Jurassic Beds *of* North Oxfordshire *and adjacent* Districts. By Edwin A. Walford, Esq., F.G.S. (Read November 19, 1884.)

[Plate I.]

A well-defined family of the Mollusca making its appearance and attaining its maximum development within a limited geologic period must necessarily be of exceptional interest to the palæontologist. Such a family, the Trigoniæ, though from their irregular dispersion and less vagrant habit inferior to the Ammonites as stratigraphical guides, supply nevertheless no unimportant evidence thereon, finding, as they do, a birthplace in the lower beds of the Lias, and in the Inferior Oolite leaping into such numerical luxuriance that Dr. Lycett has well described it as "a very metropolis of the Trigoniæ." Though fairly represented in the higher Jurassic series, yet with gradually diminishing importance notwithstanding a brief Neocomian revival, they range through the Mesozoic period, and now in Australasian seas linger as the remnant of a once dominant race.

In wealth of individual forms as well as in number of species the narrow Jurassic area of North Oxfordshire stands prominent. As elsewhere, the Lias species are few.

Liassic Species.

Trigonia lingonensis, Dumort.—In the zone of *Ammonites Henleyi* of the Middle Lias of Banbury a doubtful cast of this species has been found. I have recorded it also from the zone of *Ammonites spinatus* * at Kings Sutton and Aston-le-Wall, localities on the borders of Northamptonshire. At Preston Capes, in Northamptonshire also, it has been collected by Miss Baker †.

Trigonia northamptonensis, nov. sp. (Pl. I. figs. 4–7.)

The few immature forms of this species which had come under my notice until quite recently caused me to refer them with some degree of hesitancy to the Yorkshire shell *T. literata*, Y. & B. The adoption of a new name has seemed necessary under the additional light thrown by the acquisition of a better-developed series of examples and by an expression of opinion from a palæontologist of wider experience than myself. Though perhaps the differences between the two forms may to some extent be due to regional variation, yet we have to remember that in the course of the Lias from Yorkshire through Lincolnshire and Leicestershire, no connecting link seems to have been met with.

* "On some Middle and Upper Lias Beds in the Neighbourhood of Banbury," by E. A. Walford (Proc. Warwicksh. Nat. & Arch. Field Club, 1878).

† "On the Middle Lias of N. Gloucestershire," by the Rev. F. Smythe, M.A. (Proc. Cott. Nat. Club).

Shell ovately trigonal, moderately convex, umbones erect, pointed and antero-mesial. The specimen (fig. 5, Pl. I.) measures in height $1\frac{1}{2}$ inch, breadth $1\frac{5}{8}$ inch, depth through both valves $\frac{13}{16}$ inch. Anterior side produced and curving somewhat steeply to meet the lower border; superior border slightly convex, making but a faint angle with the lower-area border. Inferior margin of the shell rather straightened. Escutcheon concave and lengthened. Area convex, occupying about a quarter of the surface of the shell. Marginal carina depressed and not prominent; mesial line of the area indistinct; area covered with fine transverse lines. The nearly perpendicular costæ, about ten in number, proceed from the marginal carina downwards, beginning near to the umbones; they are boldly marked until they reach the transverse subtuberculate costæ proceeding from the anterior margin. The transverse costæ dip gently downwards from the anterior border. Traces of transverse striæ cover the better-preserved portion of the surface.

The example described is much less convex than *T. literata*, and in the ornamentation the perpendicular costæ are not prominent over more than a third of the surface, whereas in *T. literata* that series occupies its larger portion.

A second group of shells (figs. 4, 6, 7, Pl. I.) presents many points of divergence from the form just described. In some of them, as in figs. 6 & 7, the outline is more oblique, and the anteal costæ are either reduced to insignificant proportions, or are apparently absent. This condition much resembles the type of shell figured by Lycett (pl. xiv. fig. 4, Brit. Foss. Trigoniæ), who speaks also of the very variable ornamentation of *T. literata*. The perpendicular costæ of this variety of *Trigonia northamptonensis* enlarge as they pass downwards from the marginal carina, and cross towards the anterior or lower border.

Fig. 4 presents an intermediate stage between the forms represented by figs. 5 & 6. The anterior tuberculate costæ are seen curving slightly downwards, transversely, towards the posteal series, the space between the two series being occupied by a few scattered tubercles.

Trigonia navis, Lamk., has a more trigonal contour, and a nearly vertical anterior border. The Northamptonshire shells appear to be local representatives of the group Scaphoidæ, finding a place somewhere between *T. navis*, Lamk., on the one hand, and *T. literata*, Y. & B., on the other. Their state of preservation is far from satisfactory: the soft test has peeled off more or less by adhesion to the tenacious blue clays in which the shells are imbedded, and this has in nearly every case destroyed the beauty and prominence of the ornamentation. Perhaps the finding of better examples may ultimately allow the two varieties figured to be recognized as species.

I am indebted for my specimens to Mr. B. Thompson, F.G.S., of Northampton, who has been describing the Lias deposits of the county. The *Trigoniæ* were obtained from Moulton, near Northampton, and rough casts have also been found at Bugbrook in the

same county. The interest of the discovery is further enhanced by the recognition of the exact horizon of the fossil, at nearly the top of the Upper Lias and below Mr. Sharp's stage E of the Northampton Sand. Mr. Thompson's notes on its position agree with my own. He writes, "The shelly band, a few inches in thickness, is about two feet below the junction (with the Inferior Oolite) where now working; but the men say it dips so rapidly on *each side* of its present position that they had met with it in the same pit thirteen feet below the junction." The associated fossils are *Ammonites bifrons*, Brug., *Gresslya donaciformis*, Phil., *Inoceramus dubius*, Sow., *Protocardium substriatulum*, d'Orb., *Cucullæa*, sp., &c.

TRIGONIA PULCHELLA, Ag.—This also, an Upper Lias form, has been recorded from the neighbourhood of Northampton, though only as a Drift fossil *. Probably ere long we may hope to have a record of the discovery of the species *in situ*, as a layer containing small univalves (*Cerithium*, &c.), similar to those found by Mr. W. D. Carr, in the Upper Lias of Lincoln † associated with *T. pulchella*, has already been noted by Messrs. Thompson and Crick. The Lincolnshire horizon of *T. pulchella* appears to be much lower than that of *T. northamptonensis*, the former being at the base of the *Leda-ovum* beds, the latter towards the top.

INFERIOR OOLITE SPECIES.

The Trigoniæ of the Northampton Sand have been catalogued by Mr. R. Etheridge, F.R.S.‡, and by Mr. Sharp, F.G.S. § It should, however, be borne in mind that the Inferior Oolite of Oxfordshire neither satisfactorily agrees with the "Northampton Sand" on the one hand, nor allows of easy correlation with the Cotteswold type on the other. Inasmuch as the latter series has presented many points of relationship, I have attempted a comparison ‖, and have summarized the matter in the following table, here slightly altered:—

* "On the Drift deposits of Wymington," by W. D. Crick (Northampton Nat. Hist. Soc. Proceed. 1883).

† "On the Lincoln Lias," by W. D. Carr (Geol. Mag. April 1883).

‡ Appendix to Prof. Judd's Geol. Rutland, by R. Etheridge, F.R.S. (Mem. Geol. Surv. 1875).

§ "Oolites of Northamptonshire," by S. Sharp, F.G.S. (Quart. Journ. Geol. Soc. vol. xxvi. p. 388).

‖ "On the Relation of the so-called 'Northampton Sand' of North Oxfordshire to the Clypeus-grit," by Edwin A Walford, F.G.S. (Quart. Journ. Geol. Soc. vol. xxxix. p. 224).

Table of Divisions of the Inferior Oolite of North Oxfordshire.

STRATUM.	HORIZON.	LOCALITY.	FOSSILS.	TRIGONIÆ.
E. Cream-coloured or grey Limestone, often siliceous and sandy (Chipping-Norton Limestone)	Fuller's Earth and Inf. Oolite? ...	Chipping Norton, Rollright	*Am. arbustigerus, Patella, Neæra, Natica.*	*Trigonia signata, T. denticulata, T. producta, T. Lycettii.*
D. Sandy and marly Limestones and Marls	......	Hook Norton, Rollright, Chipping Norton......	*Am. Parkinsoni, Astarte minima, Lima cardiiformis.*	
	Am. Parkinsoni...			
C². Clypeus-grit	......	Fawler, Rollright, Chipping Norton ..	*Am. Parkinsoni, Clypeus Plottii, Terebratula globata, Lima gibbosa.*	*Trigonia costata, T. v-scripta?*
C¹. Clypeus-grit basement-bed = Lower Trigonia-grit		Fawler, Rollright, Chipping Norton ..	*Astarte minima, Rhynchonella subtetraedra, Lithodomi,* Corals.	*Trigonia angulata, T. producta, T. costata.*
	Am. Parkinsoni or *Am. Humphresianus*......			
C. Rubbly and ironshot Limestones and Marls		Hook Norton, Otley Hill	*Rhynchonella spinosa, R. angulata, Astarte minima, Isastræa Conybeari, Lithodomi.*	*Trigonia angulata, T. producta, T. Guisei, T. gemmata, T. signata, T. pullus, T. Windoesi, T. Moretoni,* var. *oxoniensis.*
B². Oolitic cream-coloured Limestones with corals	*Am. Murchisonæ*..	Coombe Hill	*Natica cincta, Am. Sowerbyi?, Ostrea Marshii, Thamnastræa Wrightii.*	*Trigonia Beesleyana, T. pullus.*
B¹. Sandy blue-hearted Limestone	*Am. Murchisonæ*..	Hook Norton, Otley Hill, Milcombe ...	*Am. Murchisonæ, A. læviusculus, A. corrugatus, Astarte elegans.*	*Trigonia Brodiei, T. striata, T. sculpta, T. spinulosa?, T. costata?*
A. „ „ „	*Am. jurensis?* ...	Hook Norton, Otley Hill	*Rhynchonella cynocephala, R. subdecorata, Terebratula trilineata, Am. jurensis?*	*Trigonia Brodiei.*

As far eastward as Chipping Norton and Fawler, in N.W. Oxfordshire, the continuity of the upper beds of the Inferior Oolite of the Cotteswold type (the Ragstones or Clypeus-grit) is easily traceable. North-eastward of these points, however, so widely different are the conditions of deposit that Mr. Hudleston has well said * :—"The beds of this region have a type of their own, and it is no use trying to force them into the ready-made clothes of other districts."

The bed (C^1) at the bottom of the Clypeus-grit (C^2) at Fawler, and that at the base of C at Hook Norton are similar lithologically, and both contain an abundance of concretionary and derived fragments. Associated with these in each locality are corals of similar species, blocks of limestone covered with oysters and pierced with *Lithodomi*, numerous shells such as *Astarte minima*, *Ostrea Marshii*, *Isocardia*, sp., *Trigonia producta*, *T. costata*, and *T. angulata*. With so many features in common, it will be safe to assume the connexion of the seas of these areas with each other at the time of the deposition of the bed, whilst the irregularity of its occurrence at Fawler, where the bed rests, as at the Duckpool-Farm cutting, near Hook Norton, upon the Upper Lias, points also to long and continued erosion in the antecedent period. The classification of these beds with the zone of *Ammonites Parkinsoni* on the one hand, or the zone of *Ammonites Humphresianus* on the other, will depend much upon whether we look to the Cotteswold or to the Dorset types for comparison. The fauna is that of the Lower Trigonia-grit, a division, according to Dr. Wright, of the zone of *Ammonites Parkinsoni*, but placed by Mr. Witchell † in the zone of *Ammonites Humphresianus*. If the remains of the bored bed represent, as seems to be probable, the well-known Upper Freestone bed, then it would point to the destruction of that stratum prior to the formation of the lowest bed of series C.

The 'Supplementary Monograph on the British Fossil Trigoniæ,' by the late Dr. Lycett, published in 1883 by the Palæontographical Society, has done much to increase our knowledge of the stratigraphical position as well as of the species of the Oxfordshire Lower Oolites. Some additional information accumulated since the materials were sent to Dr. Lycett in the early part of the year 1882 has induced me to proffer these notes to the Society.

Trigonia Brodiei, Lyc., a pretty little local species, is not uncommon in the Lower Inferior Oolite beds A and B^1. Its occurrence in any higher stratum is doubtful. It is nearly allied to *T. formosa*, Lyc., of which it may possibly be a local development. The prominent distinguishing feature between the two species consists in the more vertical position of the lower costæ of *T. formosa*. The beds A and B seem to represent the zones of *Am. jurensis* and *Am. Murchisonæ*.

* "Report of the Excursion of the Geologists' Association to Chipping Norton," by W. H. Hudleston, M.A. (Proc. Geol. Assoc. vol. v. no. 7, p. 9).

† 'Geology of Stroud,' by E. Witchell, F.G.S., p. 57. Stroud: 1882.

TRIGONIA FORMOSA, Lyc.—Though it may appear unsatisfactory to class *T. Brodiei. T. formosa,* and *T. striata* from the same horizon and locality, yet certain well-developed shells of the "*Brodiei*" type pass away into forms which agree so well with moderate-sized examples of *T. formosa* that it seems to be necessary either to make *T. Brodiei* a variety, or to admit the former into the Oxfordshire list. Locality: Hook Norton, beds A and B^1.

TRIGONIA STRIATA, Miller, is found sparingly and in an indifferent state of preservation in the beds A or B^1 of Otley Hill. In Gloucestershire, according to Wright *, it occurs in the "Cynocephala stage," whilst Lycett records it from the zone of *Am. Humphresianus* only, referring the shell from the lower zone to *T. formosa. T. striata* is catalogued as common in the Lincolnshire Limestone. Other Survey Memoirs † quote it from the Great Oolite.

TRIGONIA SIGNATA, Ag.—The four varieties of this species figured by Dr. Lycett in his Supplementary Monograph, occur in an admirable state of preservation in the higher divisions of the Inferior Oolite of North Oxfordshire. In the beds C of Hook Norton the first forms appear associated with *Astarte minima, Rhynchonella spinosa*, and many other species of mollusca, but they become the dominant fossils in the superior stages of other localities. The matrix of the latter stages is either sandy or an intensely hard compact siliceous limestone, from which the extraction of the shells is exceedingly difficult. A bored bed occurs above the Upper Trigonia-layer at Hook Norton. Some undescribed forms of *Trigoniæ*, to which I shall presently allude, were procured by me some years since from the Trigonia-bed at Sharpshill near Hook Norton. At the Priory Farm by Chipping Norton and at Grayton Quarry near Whichford numerous specimens of the several varieties may yet be obtained, but in other localities they are now rare. *T. signata*, var. *Stutterdi*, and var. *decurtata*, have both been found in C of Hook Norton and Otley Hill; and though Dr. Lycett has referred the former to the superior beds, probably it would be better to restrict the varietal name to the shell of the lower beds (figs. 9 and 10, pl. ii. Foss. Trig., Supp. 2), which is like those found at Cold Comfort near Cheltenham, and distinct from its allies of the later deposits. *T. signata*, vars. *Zietenii, rugulosa,* and *decurtata,* occur in the higher series.

Though in Yorkshire *T. signata* belongs to the zone of *Ammonites Humphresianus,* in the south-west of England Lycett gives the Upper Trigonia-grit as its only horizon.

TRIGONIA SPINULOSA?, Young and Bird.—A solitary and, unfortunately, imperfect example from bed B^1 of Hook Norton has many points of resemblance to the shell figured by Lycett (pl. iii. fig. 6, Brit. Foss. Trigoniæ). The tubercles are more distinct than in any

* 'A Monograph of the Lias Ammonites,' by Dr. T. Wright, F.R.S., p. 146 (Mem. Pal. Soc. 1879).

† 'On the Geology of the country around Banbury,' by E. Hull, F.G.S., pp. 24, 25 (Mem. Geol. Surv. 1864).

Yorkshire specimen in my cabinet. There is also a general tendency to an upward curvature of the rows of costæ, which places it in near relationship to *T. formosa*, from which, however, it differs in the marked isolation of the tubercles anteally and their evanescence in its lower half.

TRIGONIA MORETONI, var. OXONIENSIS, Mor. & Lyc., seems to be confined to the beds C of Hook Norton and Otley Hill. Young forms of *T. angulata* are difficult to distinguish from this little shell. *T. Moretoni*, according to Etheridge, is found rarely in the Collyweston Slate, and in the lower zone of the Great Oolite it seems to be well known generally.

TRIGONIA ANGULATA, Sow., occurs not uncommonly in and immediately above the coral bed (C) at Hook Norton and Otley Hill, and also at the bed at the base of the Clypeus-grit (C^1) at Fawler and Bright Hill. The ornamentation of the species is very variable. Lycett and Witchell cite it from the Oolite Marl, and also from the various beds of the zone of *Ammonites Parkinsoni* in Gloucestershire. *Trigonia clapensis* of Terquem and Jourdy *, from the "*Parkinsoni*" zone of the basin of the Moselle, appears to resemble very closely some Oxfordshire forms I have classed as varieties of *T. angulata*. According to Lycett *T. clapensis* is a synonym for *T. Moretoni*.

TRIGONIA GUISEI, Lyc., appears to belong only to the base of C. I have a large specimen, measuring three inches in height, found *in situ* in the bottom bed of the Duckpool-Farm cutting, where the lower zone of the Inferior Oolite is wanting. This caused Dr. Lycett to refer it in error to the "lower beds of the formation." Its Oxfordshire horizon is in reality that of the Lower Trigonia-grit. The species is allied to *T. Parkinsoni*, Ag., and *T. angulata*, Lyc. Mr. Witchell's specimens, which I think should scarcely be classed with the Oxfordshire shell, are from the Clypeus-grit.

TRIGONIA PRODUCTA, Lyc., finds its home in the Hook-Norton area. Though appearing in the Coral bed, it is better shown in a higher band of ironshot limestone (no. 22 of my detailed section †), also in series C. At the base of the Clypeus-grit (C^1) at Fawler, at Bright Hill near Long Compton, and in the siliceous limestone of the Trigonia-bed at Sharpshill it occurs also. Under a modified form it again appears at the base of the Fuller's Earth ‡ in a railway-cutting near Bourton-on-the-Water, Gloucestershire. The test there is thinner than that of the Oxfordshire *T. producta*, and in its ornamentation as well as contour it approaches *T. Painei*, Lyc., an abundant shell in the stratum on which the clays of the Fuller's Earth rest.

* "Monographie de l'étage Bathonien dans le département de la Moselle," par O. Terquem et E. Jourdy. Mém. Soc. Géol. de France, 1869.

† "On the Relation of the so-called 'Northampton Sand' of North Oxfordshire to the Clypeus-grit" (Quart. Journ. Geol. Soc. vol. xxxix. p. 230).

‡ Derived probably from the stratum below. Forms more nearly referable to *T. subglobosa*, Lyc., are there associated with *T. Painei*. A similar shell occurs in series C at Hook Norton.

The abundance of rolled nodules, covered often by fine colonies of Serpulæ, and also pierced by boring shells, point to a pause in sedimentation prior to the deposition of the clays of the Fuller's Earth. In the south-west of England *T. producta* is confined to the Trigonia-grit.

Trigonia approaching v-costata, Lyc.—Both *T. v-costata* and *T. conjungens* must be catalogued as doubtful species of the North Oxfordshire area. The former is common in the lowest bed of the Inferior Oolite at Moulton near Northampton, and is found also in the Lincolnshire Limestone of the Midlands. In Yorkshire it occurs in the Dogger, and in Gloucestershire in the Oolite Marl and Trigonia-grit. *T. sharpiana*, Lyc., with which this species is often associated in the Dogger and Northampton Sand, I have failed to recognize in Oxfordshire, though in the "Cynocephala stage" of Yeovil Junction, I have collected what appear to be but slightly diverging forms.

Trigonia arduenna, R. & S.—The fragment from Hook Norton, figured by Lycett in the last supplement, is, so far, the only record of this early Bathonian species of Rigaux and Sauvage.

Trigonia Lycettii, nov. sp. (Pl. I. figs. 1 & 2.)

Shell ovately trigonal, convex, height of full-sized specimen $1\frac{7}{8}$ inch, breadth $1\frac{7}{8}$ inch, width of area $\frac{9}{16}$ inch. Umbones slightly recurved, antero-mesial, anterior border moderately produced and curving gracefully with the lower border, hinge-line straight, length rather more than half the height of the shell and sloping steeply downwards; costæ about sixteen, solid and unbroken in the earlier stages, cord-like on the lower two thirds of the valve; the first four or five pass with but slight downward curvature over the surface, and form knots at the carina, passing also with slight V-shaped inflexion over the area and somewhat less prominently over the escutcheon also. The other costæ sweep downwards, curve with the lower border, break and are replaced by a few tubercles in the middle third of the valve, and then, becoming solid and very much thickened, pass upwards at a high angle to the carina, across which they (the costæ) pass with bold undulation. The area has a slight median inflexion or line only, and is crossed everywhere by the thick costæ which pass over it without interruption. There are, however, indications of fine costellæ at the posterior part of the area. The ante-carinal depression is so pronounced in one specimen as to form a double row of nodulations, one row upon the carina and another row upon the anterior side of the furrow resembling the nodulations of *T. arduenna*, R. & S.*, as figured by Messrs. Rigaux and Sauvage in their excellent memoir. The escutcheon is shallow and lengthened.

Figure 1 shows the normal and typical form. The other example (fig. 2) is almost distinct enough for a varietal name. In it the

* "Descr. de quelques espèces nouvelles de l'étage Bathonien du Bas Boulonnais" par E. Rigaux et E. Sauvage. Mém. Soc. Académ. Boulogne, 1867, vol. iii. pl. iv. fig. 4.

costæ are not only much thickened, but pass with slight interruption and with strong undulation from the anterior edge of the shell over the carina, where they are much enlarged, and across the area to the posteal border.

The species is related to *Trigonia undulata* of Agassiz *, from which it differs in the peculiar irregularity of its ornamentation.

At Sharpshill quarry near Hook Norton I have found this species in a bed of exceedingly hard siliceous limestone of the Inferior Oolite crowded with *T. signata* and yielding also *Ammonites Parkinsoni*. At Hook Norton fragments occur in the same horizon. The matrix at Sharpshill is so intractable that it is a matter of the greatest difficulty to extract specimens.

I have named the species *Trigonia Lycettii* as a slight tribute to the memory of that veteran palæontologist the late Dr. J. Lycett.

T. Lycettii, var. corrugata. (Pl. I. fig. 3.)

The contour of this variety is similar to that of the previously described form, fig. 1. The shell, however, is larger, the measurement being $2\frac{1}{4} \times 2\frac{1}{4}$ inches. The costæ are finer and much more numerous, about twenty-four, the first five or six only being unbroken; those succeeding them descend steeply from the anterior margin, whilst the lowest set, in confused arrangement, curve irregularly with the lower border. They are cord-like and knotted at the anterior part of the shell, passing into scattered tubercles towards the middle (or vanishing), and then, thickening, ascend steeply towards the carina in straight or slightly undulating tuberculate or plain ridges. An ante-carinal furrow causes the costæ to wave before passing over the carina. Area concave, covered by bold continuations of the costæ, which are knotted slightly on the carina and parted in the middle of the area by a depressed vertical line.

Locality and *position*.—Inferior Oolite, Sharpshill, as before.

Trigonia conjungens, Phill.—Specimens from beds C, of Hook Norton, and from the Clypeus-grit of Over Norton, seem to justify its mention here, though I catalogue the species with considerable doubt. It appears in Beesley's lists † of Hook-Norton fossils together with *T. Phillipsii*, Mor. and Lyc., *T. v-scripta* &c.

Trigonia duplicata, Sow., appears only as a badly preserved shell inside a valve of *T. signata*. Its position is probably D, Hook Norton. I have in my cabinet a fine example from the zone of *Am. Parkinsoni* at Avoncliffe. Lycett quotes it from the Upper Trigonia-grit also.

Trigonia gemmata, Lyc. The figure in the left-hand corner of pl. ii. of supp. no. 2 to the Brit. Trigoniæ should both in text and plate appear as no. 6, not no. 8. Both it and a pretty little varietal form in my collection have been derived from the lower part of

* Mém. sur les Trigonies, tab. x. fig. 14–16.

† "On the Geology of the Eastern Portion of the Banbury and Cheltenham Direct Railway," by Thomas Beesley, F.C.S. Proc. Geol. Assoc. vol. v. p. 7.

series C^1 at Hook Norton. Its Cotteswold position is the Upper Trigonia-grit.

Trigonia Beesleyana, Lyc., appears to be restricted to the sub-zone of *Am. Sowerbyi* at Coombe Hill, near Banbury, whence many specimens have been collected. The beautiful shell so well delineated in Lycett's Brit. Foss. Trigoniæ, pl. xvii. fig. 4, has been in my collection for nearly fifteen years.

Trigonia costata, Sow., begins with a representative of the *T. sculpta* type at the top of series B, and ranges through C at Hook Norton and Otley Hill and through the Clypeus-grit in the various Oxfordshire localities, where it attains a fine development. Wright quotes the species from the zone of *Am. jurensis*, and Etheridge from the Lincolnshire Limestone, whilst Lycett gives its Cotteswold stages from the Ragstones upwards.

Trigonia pullus, Sow., appears in bed B^2. In series C also at Hook Norton many small and a few average-sized specimens have been found. Its range through the other beds is demonstrated by fine local examples from the Stonesfield Slate, the upper zone of the Great Oolite, and the Forest Marble; Lycett gives it from the zone of *Am. Murchisonæ* upwards.

Trigonia denticulata, Ag., ranges from C to E, and exhibits, in Hook-Norton shells especially, the delicate ornamentation of the area in a beautiful state of preservation. In the West of England, according to Witchell *, it begins in the "Cynocephala-beds"; other lists show that it apparently survived through the Great Oolite period.

Trigonia sculpta, Lyc., makes its appearance in well-developed forms at the top of bed B^1 at Hook Norton, and in series C at Sharps-hill is more doubtfully recognized, associated with *Gervillia lævis* &c. It ranges through the whole of the British Inferior-Oolite zones.

Trigonia Windoesi, Lyc., has hitherto been recorded only from C of Hook Norton. Young specimens of *T. Painei*, Lyc., from the earthy limestone at the base of the Fuller's Earth near Bourton-on-the-Water, come near to this little shell.

Great Oolite Species.

Trigonia impressa, Sow. Stonesfield Slate, Stonesfield.

Trigonia undulata, Fromh. Great Oolite (lower zone), Culworth, Northamptonshire, and at Milton and Tainton Down near Burford, Oxon. The *Trigoniæ* at Culworth are associated with *Ostrea Sowerbyi* and *Rhynchonella concinna* in some limestone courses which alternate with beds of marl.

Trigonia Moretoni, Mor. & Lyc. Stonesfield Slate, Stonesfield, Great Oolite, Kirtlington, Oxon and Buckingham †, and Forest Marble, Islip and Kidlington †.

* 'Geology of Stroud,' by E. Witchell, F.G.S., p. 35. Stroud, 1882.

† 'Geology of the Country round Banbury' &c., by A. H. Green, Mem. Geol. Survey.

Trigonia pullus, Sow. Stonesfield Slate, Stonesfield, upper zone, Great Oolite, near Banbury, and Forest Marble, near Rollright.

A beautiful costate species from the upper zone of the Great Oolite at Capps Lodge, near Burford, furnishes an instance of the difficulty of finding names for the whole of the varied forms of the group. Mr. W. H. Hudleston, F.R.S., F.G.S., has kindly allowed me to examine a specimen more perfect than any in my own cabinet; and from it the following description has been written:—height $1\frac{5}{8}$ inch, width $1\frac{7}{8}$ inch, breadth of area 1 inch, breadth of escutcheon $\frac{1}{2}$ inch, depth of united valves $1\frac{1}{8}$ inch. The breadth of the area is thus two thirds that of the costated part of the shell. The umbones are pointed and recurved. The anterior border is first curved and then slightly straightened as it sweeps towards the lower border. The costæ, 27 in number, are prominently elevated with sharp ridges and deep interspaces, undulating slightly as they curve gently downwards and then cross transversely towards the carina. The marginal carina is greatly elevated, in the lower part of the shell as much as $\frac{1}{6}$ inch above the costæ; it is also boldly denticulated. The area is divided by a tuberculated median carina in the left valve, with a corresponding groove in the right valve and a prominent adjacent row of costellæ. It is ornamented by four rows of costellæ, which are decussated by transverse markings. The escutcheon is ovately cordate and is bounded by prominent tuberculate or denticulate carinæ. It has a raised cushion-like centre and numerous longitudinal lines. The area is concave.

It differs from *T. elongata* in the want of convexity near the carina, and also in its wider form; the area, however, has much similarity. The escutcheon is not that of the ordinary type of *T. pullus*, and the area is larger. Though it seems to find a place between the two species, it will suffice for the present to look upon it as a variety of *T. pullus*.

Trigonia Painei, Lyc., is found in the Great Oolite of Groves Quarry, Milton, near Burford, though it does not there exhibit the massive ornamentation of the Inferior-Oolite and Fuller's-earth forms previously mentioned p. 41.

Trigonia, sp.—Height $1\frac{7}{8}$ inch, breadth 2 inches. Shell convex. Umbo slightly recurved, antero-mesial. Surface covered with about twenty bold slightly waved costæ, which cross the shell with but a slight curve toward the lower margin. The lower seven costæ, when about a third of their length distant from the carina, are crossed and nearly obliterated by three bold rows of nodulous costæ bearing downwards almost vertically from the carina. The area takes up about a third of the shell and is convex posteriorly. Anteriorly the strong costæ cross the area, but appear to pass into fewer striæ in the lower half of the shell. It is so much like the shell figured by Morris and Lycett on tab. v. pt. ii. of their 'Monograph of the Mollusca from the Great Oolite,' as *T. Goldfussi* (subsequently altered to *T. Painei*), that for the present it seems best to let the species pass with this reference.

A single valve, and the only one I have hitherto seen, was got by me from the lower zone of the Great Oolite in the railway-cutting at Ashford Bridge, near Stonesfield.

TRIGONIA WALFORDI?, Lyc.—*T. Walfordi* is one of the allies of *T. Painei*, but differs from the latter in its more erect and narrowed contour and in its subtuberculate costæ and their arrangement. The types of the shell were got from Stow-on-the-Wold; the Oxfordshire variety from the Great Oolite of Milton, near Burford. The latter form varies from the type in the less massive character and disposition of its ornamentation. The figure has been wrongly numbered in Supp. no. 2 to Lycett's Brit. Foss. Trigoniæ, pl. ii., and should appear as fig. 6, not fig. 8.

TRIGONIA CLATHRATA, Ag.—The contour of the shell, curvature of the rows of tubercles, and the disposition and number of the rows seem to me to agree so well with Agassiz's species, that I prefer to class the Oxfordshire shell with it, notwithstanding the want of a definite horizon in the description by Agassiz *. The number and curvature of the rows of tubercles of Lycett's *T. tuberculosa* are very distinct; as in Rigaux and Sauvage's *T. clavulosa* they are more numerous, and there is in those species an absence of that downward curvature or inflexion which *T. clathrata* seems to present. The markings on the area are worn, but appear to have been fine. I have noted in other *Trigoniæ*, *e. g. T. signata*, that the fineness or coarseness of the area-markings is often due to the state of preservation of the fossil; the bolder area-markings seem to underlie the others. The only example I have seen of Agassiz's species is in the collection of Mr. B. Thompson, F.G.S., who has kindly lent it for my examination. It was got from the Forest Marble or Cornbrash of Kidlington, Oxon. *T. clathrata* is quoted by Terquem and Jourdy † from the zone of *Ammonites Parkinsoni* of their Bathonian of the Moselle region.

TRIGONIA GOLDFUSSI, Ag.—In Whiteave's 'List of the Fossils of the Cornbrash at Islip and Kidlington' this species finds a place. It may, however, be the *T. Painei* of Lycett, who has stated his reasons for rejecting *T. Goldfussi* as a British species ‡. Sharp tabulates it from both Great and Inferior Oolite of the Northamptonshire district §.

TRIGONIA FLECTA, Mor. & Lyc.—The Forest Marble of Kirtlington has yielded, so far as I know, the only Oxfordshire specimen. The intensely hard matrix makes the extraction of complete shells well-nigh impossible.

TRIGONIA TUBERCULATA?, Lyc.—The same Forest-Marble stratum at Kirtlington, in which is found *T. flecta*, has also supplied me with a small tuberculate *Trigonia* agreeing in many points with the

* 'Mémoire sur les Trigonies,' par L. Agassiz, tab. ix. fig. 9, & p. 22.

† "Monographie de l'étage Bathonien dans le département de la Moselle" par O. Terquem et E. Jourdy, pp. 109 & 161. Mém. Soc. Géol. de France, 1869.

‡ 'Mon. Foss. Trigoniæ,' by Dr. J. Lycett, p. 59.

§ "The Oolites of Northamptonshire" by S. Sharp, F.S.A., F.G.S.; Quart. Journ. Geol. Soc. vol. xxvi. pp. 383 & 388.

form I have referred to *T. clathrata*, Ag., but differing in the curvature and absence of undulation in the rows of costæ. It varies from Lycett's definition principally in the fewer rows of costæ.

EXPLANATION OF PLATE I.

Fig. 1. *Trigonia Lycetti.* Inferior Oolite, Sharpshill, near Hook Norton.
2. ——— ——— (example with solid costæ). Same locality.
3. ——— ——— var. *corrugata.* Same locality.
4. ——— *northamptonensis.* Upper Lias, Moulton, near Northampton.
5, 6. ——— ———. Same locality.
7. ——— ——— (specimen without transverse costæ). Same locality.

Discussion.

Prof. Judd expressed his sense of the great value of Mr. Walford's work in showing the relations of the several divisions of the Inferior Oolite of Oxfordshire as compared with the beds of the same age in South Northamptonshire and in Gloucestershire.

Dr. Woodward hoped that Mr. Walford's studies would enable us to distinguish which of the forms described by Dr. Lycett should be regarded as species and varieties respectively. He suggested that the difficulties might to some extent be got over by employing a trinomial nomenclature.

Prof. Seeley pointed out the importance of defining the range in time of fossil species with a view to fixing the geographical distribution. The varieties of one district become representative species in other countries.

Mr. H. B. Woodward thought that some of the difficulties in correlating subdivisions of the rocks would be removed if the stratigraphical evidence were attended to as well as the palæontological.

The Author agreed with Dr. Woodward in thinking that many of the species of Dr. Lycett must be grouped as varieties. The lithological evidence, to some extent, bears out the palæontological evidence as to the relationship of the Fawler and Hook-Norton strata.

8. *On the recent* Discovery *of* Pteraspidian Fish *in the* Upper Silurian Rocks *of* North America. By Prof. E. W. Claypole, B.A., B.Sc. (Lond.), F.G.S., Buchtel College, Akron, Ohio. (Read December 17, 1884.)

The fossils which form the subject of this paper possess considerable interest to the palæontologist for three reasons:—

1. They are the only forms of the *kind* yet announced from the Western Continent.

2. They are the first authentic fish-fossils yet found in the Silurian rocks of America, all previously-reported discoveries of a similar nature having proved erroneous in consequence of zoological or stratigraphical errors.

3. Some of them are the oldest fish and, consequently, the oldest vertebrates yet discovered in any part of the world, with the possible exception of Pander's "Conodonts," which are, however, not yet generally received into the class of Fishes.

The oldest fish-remains already known from this continent are those of the Corniferous Limestone of Ohio and of the Lower Devonian, near the mouth of the Gulf of St. Lawrence, in Canada. Palæontologically, the latter of these appears to be the earlier. The Corniferous Limestone of Ohio yields *Macropetalichthys*, *Dinichthys*, *Onychodus*, and allied forms, with a single specimen attributed to *Coccosteus*; but the Canadian beds contain *Coccosteus*, *Cephalaspis*, and *Ctenacanthus*, or a form assigned to that genus.

These, however, are all Devonian fossils, and need not detain us longer. No Silurian fish have yet been obtained in America.

Galicia has yielded at least one species from rocks considered to be Upper Silurian, the nature of which justifies the age assigned to it. This was the specimen upon which Dr. Kner, in 1847, based his memoir establishing the genus *Pteraspis*. He considered it the internal bone of a Cephalopod; but later writers have controverted his opinion, and consider the fossil a genuine fish. Prof. Lankester has named it *Scaphaspis Kneri*.

But the fish-fauna which for extent and antiquity claims the first place is that of the English Ludlow rocks. The "Bone-bed" of the Upper Ludlow has yielded two distinct forms besides fragments indicating others, and of one of these forms a single specimen has been obtained from the Lower Ludlow, a fact which, as Prof. Lankester remarks, enormously increases its age.

Of these Ludlow fossils, one kind consists of small spines with fluted surfaces, resembling those borne by Selachian or Siluroid fish. To one of these classes they were accordingly attributed by Agassiz, under the names of *Onchus Murchisoni* and *O. tenuistriatus*. Similar forms occur in Pennsylvania; these I propose to call *Onchus pennsylvanicus* (see fig. 5, p. 61).

The reference of these spines to Selachians or Siluroids may prove unfounded, and it is quite possible that when we know all the details concerning the fossils next mentioned, the two may prove to belong to the same species.

It is right to remark here that some of these fossil spines from the English Ludlow rocks have been regarded by some geologists as of Crustacean origin. However this may be, the Pennsylvanian specimens show no such affinity, but in their rounded flutings much more closely resemble genuine fin-spines or ichthyodorulites.

The second and more abundant kind of these Ludlow fossils, though now, by general consent, admitted to the class of fishes, is so strange in form and structure, and so aberrant from the usual type, that its right to that rank has been doubted and denied. The specimens are oval, thin shields or plates, folded in at the sides, and with a curved surface. They measure only a few inches in length, and formed the cephalothoracic covering of the animal, the rest of whose body was soft and unprotected, or, at most, only covered with scales.

The study of these peculiar forms has been undertaken by Professors Huxley and Ray Lankester. The former has published his results in the Journal of the Geological Society (1858), and the latter in the Memoirs of the Palæontographical Society (1867 and 1869). The former has dealt chiefly with the microscopic structure, and the latter with the outward form.

Postponing for the present further detail on this point, I will only remark that I have no intention here of asserting or defending the claim of these Ludlow fossils to the name of fishes. The authors just cited have done this in no uncertain manner.

Says the former, "Leaving Prof. Pander's 'Conodonts' out of the question, *Cephalaspis* and *Pteraspis* are among the oldest, if they are not the very oldest, of known fishes."

Again, "No one can, I think, hesitate in placing *Pteraspis* among fishes. So far from having no parallel among fishes, it has absolutely no parallel in any other division of the animal kingdom" *.

If any doubt remained in regard to the zoological position of these fossils, it has since been removed by the finding of a single specimen showing a few scales attached to the matrix behind the cephalothoracic shield. This unique and invaluable specimen has been figured by Professor Lankester in his monograph.

Assuming, therefore, as proved, the ichthyic nature of these English Silurian fossils, I propose in the first place to offer proof that the Pennsylvanian specimens belong to the same family as the Ludlow *Pteraspis*, and, in the second, to show that the strata in which they occur are as low as any which have hitherto yielded fish-remains in any part of the world.

* Though Prof. Huxley's opinion is perfectly obvious, yet the meaning of this expression is doubtful. It is true that the structure in question has no parallel in any other division of the animal kingdom, but it is equally true, as will appear later, that it has no parallel among fishes.

1. *The close Zoological Affinity of the Fossils.*

In entering upon this part of my subject, both duty and pleasure make it just to express my thanks to several friends for the very kind assistance which they have afforded me in obtaining specimens of the English fossils for comparison. In the first place my thanks are due to my old and valued friend C. W. Peach, Esq., of Edinburgh, for offering me specimens of *Pteraspis*, collected by himself many years ago in Cornwall, and of *Cephalaspis*, from the cabinet of J. Powrie, Esq.. In the second place, I must express my indebtedness to my friend and former pupil, Mr. T. Stock, of the Museum of Science and Art, Edinburgh, and to Mr. B. N. Peach, of the Geological Survey of Scotland, for obtaining and forwarding these and some other material of which I had need. Without their kind aid this part of the subject could not have been made complete.

It is scarcely necessary to dwell long upon the outward form and appearance of the fossils; they closely resemble the Ludlow species in these respects, being oval in shape and having a curved surface marked with a delicate striation (figs. 7 & 8, pp. 62, 63). But the details are different in several points. I have seen no indications of the medial posterior spine which terminates the shield of some of the Ludlow forms; the striation of the surface also shows marked distinction. Instead of flowing, as represented in Prof. Lankester's monograph, concentrically round an excentric point, like that on the shell of a *Lingula* or a *Discina*, it is very irregular. Generally speaking, several lines run round the margin, curving sharply inwards at a point which probably indicates the orbit. From these lines others radiate very irregularly towards one or several centres, sweeping over the surface, separating and anastomosing, and forming a beautiful and delicate tracery quite distinct from anything represented on Prof. Lankester's figures (see fig. 7).

Professor Lankester has separated the fossils which form the subject of his memoir into three divisions, based on the number of pieces of which the shield consists. These divisions are:—

1. *Scaphaspis.* Scutum simplex, ovale.
2. *Cyathaspis.* Scutum in quatuor partes divisum, ovale.
3. *Pteraspis.* Scutum in septem partes divisum, sagittiforme.

Of these three, *Scaphaspis* is the oldest and simplest form, and, with one doubtful exception, is the only one yet obtained from the English Silurian rocks. It is quite in harmony with these facts that the same form should prevail among the Pennsylvanian fossils. Most of them consist of a single piece, but some present appearances which suggest the probability that they possessed other plates in front and laterally. If this prove to be the case, they will approach the genus *Cyathaspis* of Lankester.

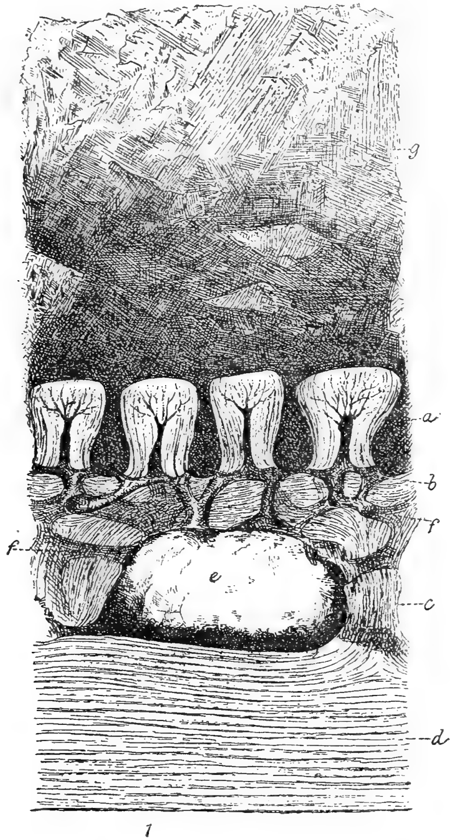
In regard to the microscopic structure of these fossils and their resemblances and differences as compared with those of the English Ludlow rocks, I must confess my indebtedness to the figures of

Prof. Huxley in the Quarterly Journal (1858). Prof. Lankester has added little upon this subject*.

Prof. Huxley describes the shield of *Pteraspis* (*Scaphaspis*) *Lloydii* as consisting of four distinct layers, which he describes thus (*l. c.* p. 275):—

"The total thickness of the section is about $\frac{1}{40}$ of an inch, and of this amount about $\frac{1}{110}$ of an inch is occupied by the inner layer,

Fig. 1.—*Vertical Section of the Shield of* Pteraspis.
(Magnified 100 diameters.)
[Copied from Prof. Huxley's figure, Q. J. G. S. vol. xiv. pl. xv. fig. 1.]



a. "Enamel"-ridges forming the outer layer. *b.* Reticular layer.
c, d. Middle and inner substances.
e. Cavity filled with matrix, one of the supposed "ossicles."
f. Vascular canal. *g.* Matrix.

* Prof. Huxley's first figure is referred to in his paper as of *Pteraspis* (*Scaphaspis*) *Lloydii*, but Prof. Lankester in reproducing it, writes of it, probably by oversight, as *Pteraspis rostratus*.

$\frac{1}{141}$ of an inch by the second layer, $\frac{1}{300}$ of an inch by the next, and $\frac{1}{200}$ by the outermost layer (fig. 1)."

"The outer layer (*a*) appears to consist of a series of papillary elevations which have a broad free end, and are attached by narrow bases, so that a triangular interspace with its apex outwards is left between every pair of elevations. The matrix filling these interspaces, and for some distance in the immediate vicinity of the outer surface, is much darker than elsewhere, and has a deep brown hue. The attached ends of the elevations pass into a whitish substance, which, under this power, looks similar to their own. It is traversed by many reddish canals, which send diverticula into the elevations (*b*) . . . . . At intervals of about $\frac{1}{70}$th to $\frac{1}{110}$th of an inch or thereabouts, thin septiform processes are given off from the reticular layer, and pass perpendicularly inwards to the inner layer; they thus subdivide the second layer into a series of irregularly quadrate spaces, corresponding with the prisms seen in the superficial view.

"The inner layer is, like the rest, whitish, and is traversed parallel with its surface by four or five much whiter streaks, so that it appears to be composed of only a corresponding number of lamellæ; but on allowing the light to pass through the section, it is at once obvious that each of these apparent lamellæ is in reality made up of many of the primitive laminæ which constitute the inner layer, and that the bright and dull white streaks are due entirely to a difference of texture or composition in the successive groups of laminæ."

The resemblance between *Scaphaspis Lloydii* and the Pennsylvanian fossils can readily be seen on reading the following description of the latter.

The shield of these fossils consists of three distinct layers, inner, middle, and outer (see figs. 2–4, p. 54). The inner layer (*a*) consists of material in which I have been unable to detect any appearance of organization, unless a delicate lamination can be so called, of which I have occasionally seen traces. The thickness of this layer varies considerably, but is usually about $\frac{1}{240}$ of an inch, or from $\frac{1}{8}$ to $\frac{1}{6}$ of the total thickness of the shield. It forms the floor on which the rest of the structure is built up, and consequently lines the whole concave side of the fossil. It shows a very faint tinge of yellow in almost all my specimens. Scattered over it, apparently without any regularity, are a number of minute circular openings which formed a means of communication between the body of the animal and the substance of the shield, and through which, we may infer, passed the organs of sensation and nutrition, or at least the latter. Some of these openings penetrate this basal layer, and enter the cavities of the cells presently to be noticed, while others pierce it opposite the walls, and continue their course for some distance in them, before or without communicating with the cells. These openings pass through the basal layer almost or quite at right angles, but in most cases a small deviation may be noticed. They are about $\frac{1}{600}$ of an inch in diameter, but may be distinctly seen and counted with the help of a hand lens; among them are a few of smaller size. Both surfaces of this layer are uneven, and by this means the varia-

tion in thickness above mentioned is produced. In almost all specimens the upper surface shows adhering reddish or yellowish matter, from which it is difficult to free it. This matter is doubtless a portion of the crystalline substance filling the cells of the next layer.

Some have used the term " enamel " in writing of this layer, but I have been quite unable to see any trace of that structure in it. Instead of prisms it rather appears to be stratified, so that the term " nacreous," applied to *Pteraspis* by Prof. Huxley, would more accurately describe it. There is, however, no appearance of the pearly lustre that characterizes true nacre.

The second layer (*b*) forms the thickest portion of the shield, and may be termed the cellular layer. It consists of a number of cells formed by party walls of a material resembling in appearance that composing the basal layer. These cells have no constant outline, but for the most part have 4, 5, or 6 sides. Nor have they one size, the larger being as much as $\frac{1}{40}$ of an inch in their longest dimensions, while others measure less than a fourth of this. In shape too they range from nearly square to oblong and hexagonal. The walls that form them are equally variable in size, ranging from $\frac{1}{300}$ to $\frac{1}{150}$ of an inch in thickness. The angles of these cells are rounded, the partitions being thicker there than elsewhere. The walls stand for the most part vertically, or nearly so, on the basal layer, and support on their other ends the third layer next to be described. As already mentioned, some of the circular vessels enter them, and remain in them for some distance, perhaps through their whole height; others lie partially in the cell-wall, and partially in the cell.

The height of the walls, and consequently the thickness of the second layer of the shield is about five times that of the basal layer, or about $\frac{1}{50}$ of an inch. The cells are filled with infiltrated calcareous matter, which under the action of the weather is dissolved out, leaving an exceedingly brittle cellular mass to represent the original shield.

The third layer (*c*) deserves the name of the vascular layer, containing as it does a perfect system of vessels imbedded in its substance. This substance is the same in appearance as that which composes the basal and cellular layers, and is continuous with them. Instead, however, of being solid, or nearly so, it is traversed by vessels, the presence of which enables us to divide it into two portions. The first and lowest of these lies immediately over the covering layer of the cells, and contains a set of large vessels running parallel with the striation of the outer surface (fig. 4). The diameter of these vessels is equal to the thickness of the covering and basal layers, or about $\frac{1}{240}$ of an inch. They are perfectly even in outline, but retain approximately the same diameter, as far as I have traced them. These vessels communicate with the cells through openings in their covering layer, apparently forming in this way a connexion with every cell over which they pass.

They likewise communicate by short branches of about half their own diameter, and tapering toward their outer ends, with another set of vessels or channels running parallel with and between them, of somewhat smaller calibre and more regular margin, lying slightly

above them in the upper division of the vascular layer, and below the minute channels of the upper and outer surface, with which they are apparently continuous. These highest canals, to which possibly the term furrows would be more applicable, have no branches or outlets, so far as I have been able to determine, except the passages just mentioned, nearly as wide as themselves, whereby communication is effected with the vessels lying below them, and already described. Both may be readily seen sectionally and longitudinally by cutting thin slices of the shield in the proper direction (see figs. 2, 3, 4).

Figs. 2–4.—*Sections of the Shield of* Palæaspis.

Fig. 4.

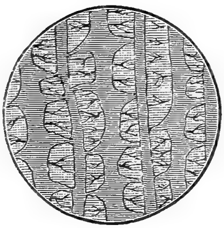


Fig. 2.

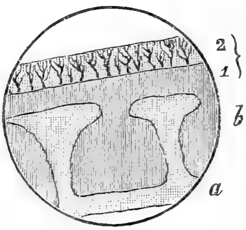


Fig. 3.

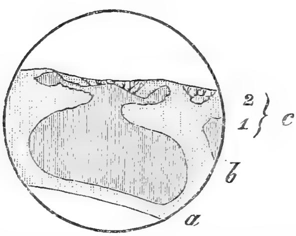


Fig. 2. Vertical longitudinal section showing (*a*) basal layer; (*b*) cellular layer; (*c*) vascular layer, (1) lower portion, (2) upper or tubular portion.
Fig. 3. Vertical transverse section, showing (*a*) basal layer; (*b*) cellular layer; (*c*) vascular layer, (1) lower, (2) upper portion.
Fig. 4. Horizontal section through vascular layer of shield, showing the lower branching vessels, the upper vessels or channels, and the tubules (seen from below).

Lastly, there yet remains to be described the most remarkable part of this outer or upper vascular layer. To this I have given the name of the tubular division. From the larger and lower of the two sets of vessels just described and from its upper side there issue a vast number of minute tubules which branch and run to right and left, and upward from the parent vessel, forming a minute and beautiful forest-like growth. Filled as they are with opaque matter they stand out distinctly, like dendrites on marble, on the light yellow surface of the material of the vascular layer. They do not form any connexion with the large channels or furrows lying to right

and left of them, but all direct their course more or less obliquely to the upper, outer surface, where their finest branches detail out and end. They perhaps form a communication with the outside; but I have not been able to see their terminations. In some sections it appears as though an extremely thin transparent layer existed, covering and sheathing the whole, but of this I am not absolutely certain.

The agreement between the above description and Prof. Huxley's account of *Scaphaspis Lloydii* is so close that no reasonable doubt can be entertained regarding their close relationship. At the same time certain distinctions exist which, considered in addition to those of external form and markings, have prevented my placing it in the same genus.

Judging from Prof. Huxley's figures, and the examination which I have been able to make of the structure of the English *Scaphaspis*, the vessels in the *reticular* layer pursue a very irregular course; hence this name. This is not the case in the fossils under consideration. Their vascular system (fig. 4) exhibits a regularity and parallelism of which the figures of *Scaphaspis* afford no trace. This alone instantly differentiates the two. Moreover, the beautiful forest-like appearance of the tubules radiating from the vessels is much more marked in consequence of this regularity than in the engraving of *Scaphaspis*. Lastly, I have seen no trace of the crenulation on the edge of the superficial striæ of which Professor Lankester makes mention.

These, with some minor considerations, induce me for the present to refrain from placing these Pennsylvanian fossils in any of Lankester's genera, and I propose therefore to refer them to a new provisional genus to which I have given the name PALÆASPIS*.

Another point must not be omitted, because it forms to the anatomist one of the most remarkable features in the structure of these shields. In none of them, either English or American, has any trace been discovered of true osseous tissues. The bone-cells or *lacunæ*, and the tubules or *canaliculi* connecting them are totally absent, unless the minute tubular system above described be considered representative of the latter. This remarkable fact was one of the chief, perhaps the chief objection to admitting the claim of these fossils to a place among the Vertebrata. But the objection has been overruled, and consequently the line separating the Vertebrates from the Invertebrates rendered to that extent less distinct.

Professor Lankester has, in his monograph, established the subfamily "Heterostraci" to receive those forms devoid of true bony tissue. He has thus divided Huxley's family of Cephalaspids into two parts, retaining in the higher of these (the "Osteostraci") all those forms which, like *Cephalaspis*, possess bone-cells and tubules (*lacunæ* and *canaliculi*).

So profound an anatomical distinction merits, it appears to me,

* The name *Glyptaspis* has appeared by oversight in one or two preliminary notices in magazines in reference to these fossils. Its occurrence was accidental, and it must therefore be considered merely a synonym.

more marked recognition than this from the systematist. It differentiates the animals of this gronp from all the rest of the Vertebrata possessing a hard skeleton. It may or may not be an indication of approximation to lower and older forms. But in either case so marked and significant a feature in the structure can scarcely be satisfied with subfamiliar distinction in the classification. I therefore propose to raise these aberrant forms, the number of which is increasing, into a distinct family under the name of Pteraspidians (Pteraspidæ), and to limit the name Cephalaspidæ of Professor Huxley to the forms composing Professor Lankester's group of Osteostracans.

2. *The Stratigraphical Horizon of* Palæaspis.

In the correlation of the Pennsylvanian strata here concerned with those of England, there is fortunately little difficulty in establishing certain definite horizons in both, which from a palæontological point of view may be regarded as equivalents. As may be seen in the table (p. 59), the English Lower Ludlow lies on the horizon of the Water Lime of Pennsylvania and New York. This correlation rests mainly on the presence and first appearance in both of huge Crustaceans of the types of *Eurypterus* and *Pterygotus*. On both sides of the Atlantic this horizon is especially characterized by these forms. On both sides they suddenly attain in this stratum very great prominence, and from it they rise into higher, but are scarely known in lower beds.

The Lower Ludlow contains the oldest vertebrate fossil yet known, the single specimen of *Scaphaspis ludensis* found in 1859. The Water Lime of Middle Pennsylvania has yielded no remains of fish, and it lies about 300 feet below the place of the locally absent Corniferous Limestone, the lowest American fish-bearing horizon. Below the Water Lime lies the great mass of coloured shale forming the medial part of the fifth group of Rogers (Geol. Survey of Penns.). This is divided in Middle Pennsylvania as follows:—

	feet.
The Grey Shale	200
The Variegated Shale	700
The Red Shale	700

At the top of the second division lie some thin beds of variegated Sandstone which I have named "The Bloomfield Sandstone." In this bed were found the fossils here described. It is exposed near New Bloomfield, Perry Co., Pennsylvania.

In a paper recently read before the American Philosophical Society and printed in their Proceedings for 1884, I have discussed the evidence for the age of the "Fifth group" of Pennsylvania. Space will not allow the reproduction of the argument here, but in that tract I have shown that the shales above mentioned are the equivalent or, rather, the continuation of the Onondaga Shale of New York, a series immediately underlying the Water Lime.

On this view of the correlation of the English and American strata, the Onondaga Salt group has no equivalent in England. It is so represented by Sir R. Murchison (Siluria, p. 472), who in this

place quotes from Sir A. Ramsay. The Ludlow rocks are considered by these writers as the correlates of the lower part only of the Lower Helderberg (Water Lime) of New York, leaving the upper portion of the Lower Helderberg also without any English equivalent. In both these respects the views of Professor James Hall coincide with those above stated. In the 'Palæontology of New York' (vol. iii. p. 34) he writes:—

"Since the presence of *Eurypterus* is regarded as marking the uppermost strata of the Silurian system of Great Britain, our Lower Helderberg group constitutes a series of strata not recognized and probably not existing in the British Isles."

Professor Hall then gives the following table illustrating his views on the correlation of these beds:—

New York.	*Great Britain.*
Lower Helderberg.	
Water Lime.	Lesmahago Beds.
Onondaga Salt Group.	
Niagara Group.	Wenlock Limestone.

The inference is reasonable that these Pennsylvanian Pteraspids are older than the *Scaphaspis ludensis* of England, by the time required for the deposition of 200 feet of strata.

To avoid returning to this subject, I will here add that the English Wenlock group is placed on the horizon of the American Niagara on evidence which has never, so far as I know, been disputed. Sir R. Murchison wrote in 1859 (Siluria, p. 460):—

"The Niagara shales in all respects resemble the well-known Wenlock shale of Britain; whilst the chief or central mass of the Upper Silurian rocks in North America is that called the Niagara limestone, which unquestionably represents the Wenlock and Dudley limestones of England as well as of Gothland in the Baltic. These rocks appear to contain a greater number of fossils identical with those of Europe, than do the Lower Silurian strata of the same districts;" among them are the following:—

List of Fossils common to the American Niagara and the English Wenlock Limestone.

Calymene Blumenbachii, *Brongn.*, now C. niagarensis, *Hall.*	Orthis hybrida, *Sby.*
Homalonotus delphinocephalus, *Green.*	Orthoceras annulatum, *Sby.*
Bumastus barriensis, *Murch.*, now Illaenus Ioxus, *Hall.*	Eucalyptocrinus decorus, *Phill.*
Rhynchonella cuneata, *Hall*, now Rhynchotreta cuneata, *var.* americana.	? Bellerophon dilatatus, *Sby.*
Rhynchonella Wilsoni, *Sby.*	Favosites gothlandicus, *Lam.*
? Pentamerus galeatus, *Dalm.*	Favosites alveolaris, *De Blainville.*
Orthis elegantula, *Dalm.*	Halysites catenulatus, *Linn.*

Excluding two species from the list, for the presence of which in the Niagara I can find no evidence, and considering the close resemblance of the three that now pass under other names, we have twelve species common to the two groups. Their equivalence admits of no question.

Traces of Fish in the Onondaga Red Shale.

About 1000 feet lower in the Onondaga group I have found two or three thin beds containing comminuted scales. They are associated with other beds containing in abundance *Leperditia alta.* They are so thin and fragmentary that I have been unable to make a complete examination of them. They consist, so far as I have determined their structure, of homogeneous material destitute of bone-cells and canalicules, but resembling in all respects the solid layer of *Palæaspis.* From their condition and the appearance of the rock, I have been sometimes inclined to consider them coprolitic in origin. In any case they carry back the existence of fish by an interval represented by about 1000 feet of strata.

Traces of Fish in the Iron Sandstone.

Nor is this quite the whole. Underlying the Red shale by about 350 feet, and consequently about 700 feet below the relics last mentioned, is the Iron Sandstone, a bed of hard coarse material, the position of which I have determined (in the paper already referred to) near the middle of the Clinton group, and at least 900 feet below the Ore Sand-rock, a well-known horizon in Pennsylvania, containing numerous Clinton fossils, for example—

Beyrichia lata, *Vanuxem.*
Ormoceras vertebratum, *Hall.*
Calymene Clintoni, *Vanuxem.*

Its horizon is consequently beyond dispute.

In this sandstone I have found a thin layer closely packed with broken plates somewhat similar to those last mentioned, but in better condition. They are very thin, but almost every well-preserved fragment shows a superficial striation closely resembling that of *Palæaspis.* Accompanying them are a few fine spines much like those above described under the name *O. pennsylvanicus.* For these I propose the name *Onchus clintoni* (p. 61, fig. 6).

Besides the actual relics of fish already mentioned from the Iron Sandstone, the bed is charged with small white pellets about as large as peas. An examination of one of these by Mr. A. S. M^cCreath, Chemist to the Pennsylvania Survey, gave the following result:—

Partial Analysis of the "White Specks" in Iron Sandstone.

Phosphorus	6·478
Representing Phosphoric Acid	14·857
Phosphate of Lime	32·39

I infer therefore the coprolitic nature of these pellets, and the evidence thus obtained is confirmatory of the statements already made.

An examination of the appended Table of strata (p. 59) will summarize to the eye the results here given, and will bear out the assertion made at the outset that we now have evidence of the existence of fish in Pennsylvania at an earlier date than in any other part of the world (Conodonts of Pander excepted).

Correlation of the Lowest Fish-bearing Strata in England and North America.

Great Britain.	New York.	Middle Pennsylvania.	Ohio.	Canada.
Lower Old Red Sandstone. *Cornstones. Tilestones* (Ledbury). *Pavingstone* (Forfar). *Slates* (Cornwall).	*Corniferous Limestone.* Oriskany Sandstone.	Oriskany Sandstone.	*Corniferous Limestone.* Oriskany Sandstone.	*Campbellton beds* (near Gaspé).
Upper Ludlow.	Lower Helderberg.	Lower Helderberg.		
Lower Ludlow.	Water Lime.	Water Lime.	Water Lime.	
	Onondaga. Gypseous Marl. Variegated Marl. Red Shale.	Grey Shale. *Variegated Shale.* *Red Shale.*		
Wenlock.	Niagara.			
Upper Llandovery. Mayhill Sandstone. *Pentamerus*-Limestone.	Clinton. Upper Green Shale. Limestone and ore. Lower Green Shale.	Clinton. Upper Green Shale. *Sandstone and ore.* Lower Green Shale.	Clinton.	
Lower Llandovery.	Medina and Oneida.	Medina and Oneida.	Medina ?	

The beds that have yielded fish-fossils are marked by *Italic* letters.

Appendix.

Former reported Discoveries of Fish-remains in American Silurian Rocks.

The discovery of fossil fish in the Silurian rocks of North America has been announced on several former occasions; but in every case investigation has shown some mistake.

Dr. Newberry, in his "Monograph on Fossil Fishes" in the 'Palæontology of Ohio' (vol. i.), has alluded to four such instances, and says that these are all that have come to his knowledge. They are the following:—

1. In the second volume of the 'Palæontology of New York' Prof. Hall described and figured a large spine under the name of *Onchus Dewii*, from the Niagara group of Lockport, N.Y. This is now, however, admitted to be a spine of a Crustacean. In the same place Professor Hall alludes (without figuring them) to other species from the Shaly Limestone of the Lower Helderberg and from the Clinton group. What these were I do not know, but presume that they proved to be of a similar nature *.

2. Hugh Miller, in his 'Footprints of the Creator,' p. 143, copying from the 'American Journal of Science,' 2nd ser. vol. i. p. 62, gives a figure of a large fin-spine said to have been found in the Onondaga Salt group. It has been proved to be a specimen of *Machæracanthus major* from the Onondaga Limestone of the Corniferous group.

3. Messrs. Norwood and Owen, in the 'American Journal of Science,' 2nd ser. vol. i. p. 367, described a new fossil fish from the Upper Silurian rocks of Indiana, and the error has been copied several times by other writers. It was a head of *Macropetalichthys* from the Corniferous Limestone.

4. Dr. Newberry, quoting Sir Charles Lyell ('Travels in North America,' 1842, vol. ii. p. 37), says that Sir Charles was informed by Professor H. D. Rogers that he and his brother "had traced the scales of fishes through strata of Clinton age from the south-western part of Virginia to the north branch of the Susquehanna in Pennsylvania." In the light of the facts recorded in the preceding paper this is a somewhat remarkable statement; but in the 'Geology of Pennsylvania,' vol. ii. p. 824, Professor Rogers writes:—

"The earliest date at which actual fishes appeared in the Appalachian or Palæozoic seas of North America was that of the Post-meridian strata, numerous specimens of the ganoid class having been recently found in the upper Cliff or Corniferous limestone of Ohio.

* In this connexion a rather singular and surprising statement may be noticed. Prof. Hall says (*l. c.* 1852):—"In England we have positive evidence of the existence of fish-remains in strata of the age of our Trenton limestone and Hudson-river groups." It is hardly necessary to add that this statement must rest on some misconception and that no foundation for it has ever existed.

This rock is very nearly on the horizon of the lowest Devonian of Europe, in which corresponding ichthyic remains are well known."

Professor Rogers goes even further and adds, "It must be enunciated as a general fact that hitherto no traces have been discovered of any vertebrate animal whatsoever during all those earlier Palæozoic ages which are embraced in the Cambrian and Silurian periods of the English geologists, or the equivalent Primal, Auroral, Matinal, Levant, *Surgent*, and *Scalent* periods according to the nomenclature of the Pennsylvania Survey"*.

To reconcile these quotations is difficult. Professor Rogers could not well have forgotten seeing fish-scales in the Scalent and Surgent groups had he really done so. Such forgetfulness would be especially difficult to one who believed that even in Europe no fish-remains of that date were known. Sir Charles Lyell's character for accuracy is too well known to need assertion. It is possible that Professor Rogers saw the scales, for they were there. It is also possible that Sir C. Lyell's memory was at fault. Altogether it is a rather singular example of divergence between the statements of two eminent geologists.

Description of the Species.

ONCHUS PENNSYLVANICUS, sp. n. (Fig. 5.)

Spine, when complete, about half an inch long, with a diameter at base of about one eighth of an inch, very slightly curved and consisting of an inner core (perhaps only composed of material filling an original cavity) and an outer sheath. The outer portion shows a fluted surface, with eight ridges in the quarter of the circumference which is visible; ridges rounded, their height being about half their breadth; the furrows between them acute at base and formed merely by the edges of the two ridges without any breadth.

Locality and horizon. Perry county, Pennsylvania, in the Bloomfield Sandstone or uppermost member of the Onondaga Variegated Shales.

Fig. 5.—Onchus pennsylvanicus, *showing fluted surface and core.*

Fig. 6.—Onchus clintoni.

ONCHUS CLINTONI, sp. n. (Fig. 6.)

Spine slightly curved, the part visible about half an inch long and showing on the one side 5 rounded low ridges meeting each other

* This statement appeared in 1858.

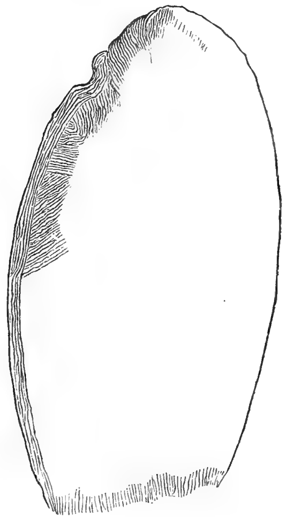
without intervening spaces; furrows between ridges consequently angular. Diameter at base about one eighth of an inch.

Horizon and locality. Clinton group, Iron-sandstone, Perry co., Pennsylvania.

PALÆASPIS, g. n.

The genus has been sufficiently described in the body of the paper.

Fig. 7.—*Outline of Shield of* Palæaspis americana. (Nat. size.)



The striation is shown only over a part of the shield, but extends really over all.

PALÆASPIS AMERICANA, sp. n. (Fig. 7.)

Shield elliptical in outline, truncate at one end, convex on upper surface, between two and three inches long; lateral edges rolling in under the upper surface; thickness not exceeding $\frac{1}{40}$ inch over its whole extent. Upper surface covered with a tracery consisting of fine, delicate, flowing, depressed lines branching and anastomosing, but in general keeping directions rudely parallel, often abruptly curving near the end from both sides towards the medial line, where they terminate without ending in a spine.

Locality and horizon. Perry county, Pennsylvania, in the Bloomfield Sandstone or uppermost member of the Onondaga Variegated Shales.

PALÆASPIS BITRUNCATA, sp. n. (Fig. 8.)

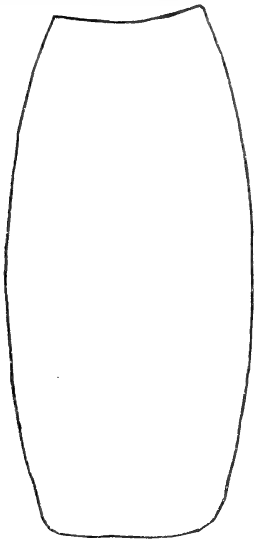
Shield elliptical, truncate at *both* ends, more convex than *P. ame-*

ricana. Ends straight or concave. In other respects, in form and in ornament, this species does not differ from the former.

The abruptly truncate appearance of this species suggests the probability that at least a rostral plate adjoined the cephalo-thoracic shield, in which case it most likely possessed also marginal pieces. Such a structure would bring it into close relation to Lankester's *Cyathaspis.*

Locality and horizon. As those of preceding species.

Fig. 8.—*Outline of Shield of* Palæaspis bitruncata. (Nat. size.)



Discussion.

Dr. Woodward said he was glad the author had discovered the canaliculate layer in these fossils. Professor Lankester could not detect it in the specimens examined by him. The oldest of these American remains certainly appeared to be more ancient than any known in Europe. He referred to the discovery by Dr. Lindström of the remains of a Scorpion in beds of Upper-Ludlow age in Gotland, and stated that a specimen so similar as certainly to belong to the same genus, if not to the same species, had been discovered at a still earlier date in the Upper Ludlow of Lanarkshire by Dr. Hunter; although owing to the illness of Mr. Peach, to whom it was sent, its occurrence had not been recorded.

Professor T. Rupert Jones doubted if the older specimens described by the author were as well defined as those of the upper beds, and remarked upon the gap between the Wenlock and Ludlow beds

that must be assumed to exist in the European series of deposits if the author's stratigraphical views were correct.

Mr. Hopkinson said that there could hardly be a gap between the Wenlock and Ludlow series in this country, seeing that so many species of Graptolites, and also other fossils, passed uninterruptedly from the highest beds of one into the lowest of the other, that, from a palæontological point of view, it was difficult to draw the line between them.

Mr. Blanford said that Professor Claypole did not assert that any break occurred between the Wenlock and Ludlow, but apparently the stages were more numerous in America than on this side of the Atlantic. He also indicated, from his own experience, how difficult it often is to decide whether a break occurs between different beds.

9. *On a* NEW DEPOSIT *of* PLIOCENE AGE *at* ST. ERTH, *near the* LAND'S END, CORNWALL. By the late SEARLES V. WOOD, Esq., F.G.S. (Read November 5, 1884.)

IN the autumn of 1883 my friend Mr. F. W. Harmer, F.G.S., being at Penzance, chanced to hear of the occurrence near that place of a bed containing some shells not recognized as now living on the coast of Cornwall. Being introduced to Mr. Thos. Cornish, of Penzance, as a gentleman who had taken an interest in the matter, he got him to forward to me such of the shells as he possessed. These consisted of specimens of *Nassa mutabilis*, *N. serrata*, and *Turritella triplicata*; and I sent them to Mr. Robert Bell, F.G.S., to see and to show to Dr. J. Gwyn Jeffreys. We all three doubted their being genuine, the *Nassæ* presenting, indeed, the appearance of imperfect fossilization.

Sometime afterwards Mr. Cornish sent me some more specimens. These removed my doubts; but from the incredulity with which Mr. Bell was met in the comparisons which he made of them for me with specimens in the recent and foreign collections of the British Museum, I pointed out the desirability of having the pits reopened before I brought the matter to the attention of the Society, and this Mr. Cornish determined to have done.

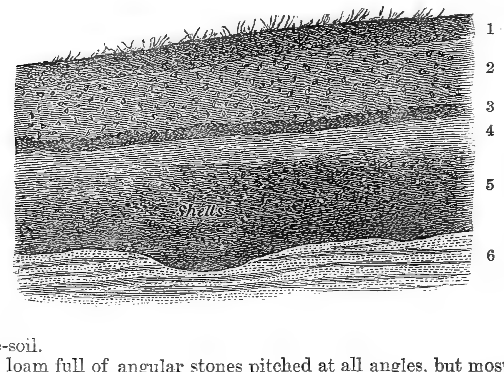
The past exceptionally dry summer in Cornwall has afforded the opportunity for this; and on the 26th of August last a party consisting of our Foreign Secretary, Prof. Warington Smyth, and twelve other gentlemen, mostly geologists, residing in the county, accompanied Mr. Cornish and witnessed the reopening of one of the disused excavations, obtaining also a few of the shells. Some of the clay then extracted Mr. Cornish despatched to me; and from it and more since had I have extracted several of the species mentioned in the sequel, including among them two out of the three first to sent me by Mr. Cornish.

In the interval Mr. Cornish got together what further specimens he could hear of, including some entrusted to him by Mr. Goodman, of St. Erth, and put me into communication with Mr. Nicholas Whitley, of Truro, who had brought the subject of this fossiliferous bed incidentally before the Royal Geological Society of Cornwall in 1882, and Mr. F. W. Millett, of Marazion, who was engaged in searching the material of it for Ostracoda and Foraminifera, both of whom sent me what molluscan remains they had obtained from it. Since the reopening of the pit, also, the Vicar of St. Erth has interested himself in the matter, and sent me some further contributions to the total species that I have in this way got together.

Mr. Cornish informs me that the area occupied by the bed, so far as its extent is known, does not exceed an acre, the first excavation in it (the one that he has now got reopened) having been commenced about 50 years ago, for the moulding sand upon which the

fossiliferous clay rests, but abandoned some ten years since. In 1881, clay being required for the puddling of a dock which was then being constructed at Penzance, the excavations were at his instance renewed, the upper (yellow and unfossiliferous) clay, into which the blue clay yielding the shells passes upwards, being found suitable for this purpose; since which the pits have again fallen into disuse. It was during this renewal of the excavations that Mr. Whitley visited them, obtained the shells mentioned in his paper, and recorded the sections in his note-book from which the one I herewith give (fig. 1) is taken. Mr. Cornish exhibited at the Jubilee

Fig. 1.—*Pit near St. Erth Vicarage, from the Note-Book of Mr. Nicholas Whitley, of Truro.*



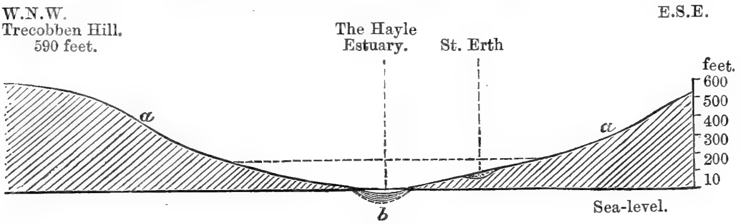
1. Surface-soil.
2. Clayey loam full of angular stones pitched at all angles, but mostly upright, 3 to 5 feet. (This is probably the formation described under the letter γ in my Newer Pliocene Memoir in Quart. Journ. Geol. Soc. vol. xxxviii. p. 720, under which the ancient beaches of the south coast are buried, and which has a great extension in Cornwall.)
3. Stones cemented with oxide of iron, &c., 6 to 12 inches.
4. Tenacious yellow clay with unrecognizable fragments of some bivalve shell passing down into—
5. Blue clay, very irregular, 3 to 5 feet (and more in places), and containing marine shells.
6. Fine sand, base not exposed, but described by the workmen as having gravel and rubble at bottom, resting on rock.

meeting of the Falmouth Polytechnic Institution in 1882 some specimens of the shells, but the first (and only) scientific notice which has been given of the bed is a short paper by Mr. Nicholas Whitley, published in the Transactions of the Royal Geological Society of Cornwall for January 1882, entitled "On the Evidence of Glacial Action in Cornwall," in which he incidentally refers to the St. Erth bed, and gives a list of ten species of Mollusca that he had obtained from it, and had submitted to Mr. G. B. Sowerby, Junior, for identification.

On my writing to Mr. Whitley, and pointing out to him that he had been mistaken in referring the bed to Glacial age, he not only

put these specimens into my hands, as well as some more that he had subsequently procured, and sent me his note-book with the sections, but, to satisfy my inquiry as to the elevation of the bed, visited the spot again, and ran a set of levels from mean tide-mark on the Hayle shore to the pit, by which he ascertained that the elevation of the part from which he obtained his specimens is 98 feet above ordnance datum, the surface of the ground being about 15 feet higher.

Fig. 2.—*Section across the Valley of the Hayle at St. Erth.*



a, a. Ancient rocks. *b.* Recent and Prehistoric silt.
---- Line showing the probable surface of the sea in the strait in which the St. Erth shells lived.

The pits are on the eastern slope of a tract of low ground that extends from Penzance and Marazion on the south coast, to St. Ives Bay on the north coast of the county, cutting off the high ground of the Land's End district from the rest of Cornwall. The bottom of this low tract is occupied by beds of peat and of estuarine or marine silt, altogether unconnected with the bed in question, and which, from the specimens of Mollusca sent to me by Mr. Cornish from some excavations in them, appear to be of that recent date which marks the last depression of Britain * and belongs to the Neolithic period.

As this tract cuts through the highland formed of ancient rocks, it must at the time of the deposit of the St. Erth beds have been a strait, separating the Land's End region from the mainland of Britain; but no other indication of this deposit has hitherto been detected.

[The author here added a provisional list of Mollusca obtained by him to the number of about 50. As this list was confessedly imperfect, he expressed his intention of preparing and publishing hereafter a full description of the fauna, with figures of the new species; it was withdrawn by him with the permission of the Council.]

Of the species obtained by me from the bed, three, viz. *Cypræa avellana*, *Nassa granulata*, and *Melampus pyramidalis*, are Red-

* The succession of events traced in my memoir on the Newer Pliocene period in England, Q. J. G. S. vol. xxxviii. p. 732, terminates just prior to this last depression, which is only briefly adverted to, and then only in respect of the amount of depression that has taken place.

Crag forms not known living. The first two are probably also species of the Miocene of Touraine, as *Cypræa affinis*, and *Buccinum graniferum*, of Dujardin.

The great muricated form of *Calyptræa chinensis* does not occur in the Miocene of France, the form there being small. A large form of the species is figured by Hörnes from the Vienna beds.

Nassa serrata, and all the forms of it figured as distinct species by Bellardi, as well as *N. Emiliana*, do not occur above the Lower Pliocene; *N. serrata*, *N. Emiliana*, and one other species of the group (*N. bisotensis*, var. A) occur also in the Upper Miocene. None are known living.

Nassa recticostata is a species of the Upper Pliocene only. It is not known living.

Turritella triplicata and *Ringicula buccinea* do not live north of Vigo (lat. 42°), whence they range southwards to the Canaries, and through the Mediterranean. Both are among the commonest species of the Coralline Crag.

Nassa mutabilis, as well as all the *Nassæ* of that group, and *Euthria cornea*, are only known as fossils from South European beds. In the living state *Nassa mutabilis* and *Euthria cornea* range through the Mediterranean; but outside that sea, their northernmost place of occurrence is Cadiz, in lat. 36° 30′. The shells figured by Brown, Nyst, and others, as *Fusus corneus*, belong to a group of which *Fusus islandicus* is the type, and which inhabits the North and Arctic Seas, and occurs in the North-Sea Crag, older and newer.

Natica millepunctata is, in the living state, confined to the Mediterranean; but, in the fossil, it occurs in the Miocene and Pliocene of Southern Europe in general. The Coralline and Red Crag form, *N. multipunctata*, my father did not consider identical with it.

Artemis exoleta is represented in the Red Crag by *A. lentiformis*, J. Sow., a closely allied but identical shell. It is not known from the Coralline Crag, but is regarded as a Miocene species. It is also a South-Italian Pliocene fossil, and ranges living from Norway to the Mediterranean.

Of the other species obtained, save those peculiar to the deposit, most range in the living state from Norway to the Canaries, and through the Mediterranean.

One of them only is known to reach the Greenland or Spitzbergen Seas also. Two range no further south than Britain, as far as yet known. Some of these occur so far back as the Miocene, others not further than the Pliocene, while six of them, all minute living species, are not known (except in this deposit) as fossils at all, or only as fossils of the latest beds. *Nucula proxima* is a living North-American shell, occurring in the Coralline Crag as *N. trigonula*, but it may be the same as a living Norwegian species, *N. tumidula*.

The character of the Mollusca, as a whole, is essentially southern, no peculiarly arctic shell having as yet occurred.

Both in the positive and negative aspects of this group of Mollusca

(for none of the many peculiarly tropical genera that occur in the Miocene are present in it) we seem to have evidence of a Pliocene age for the bed, and, I think, on the whole, a preponderance in favour of Newer, rather than Older Pliocene. The relation of the fauna is more in the direction of the Italian Pliocene than in that of the Pliocene of North-western Europe.

At the outset of my investigations I thought it likely that the bed would prove to belong to that very late part of the Newer Pliocene period called now Quaternary, when the small submergence took place which I have, in my memoir on that period in England *, traced as having preceded the minor Glaciation, and to which I have referred the *Cyrena*-formation, and with which the rich bed of marine Mollusca at Selsey in Sussex is connected. This Selsey bed contains some species of Mollusca which now live only to the south of the British shores, though, like its species in the marine beds coeval with it, from Essex northwards over the east side of England, which present no such southern indications, these are all living species; and I thought that as the difference in this respect between these beds, thus coeval with the Selsey one, is evidently due to the presence, during their accumulation, of an isthmus connecting the South-east of England with the continent, which prevented the water which had access to Sussex from the Atlantic having any access to the North Sea, except round the North of Scotland, the more westerly position of the Land's End might be the reason for the still more southern aspect of the St. Erth Mollusca; but the species I afterwards got together comprised so many not known from Selsey, and, withal, some known only in the fossil state, that this view became untenable. We must therefore seek a more ancient period to which to refer it; and as between the Selsey bed and the Red Crag we have only beds belonging to successive stages of the submergence that accompanied the great glaciation of England, in all of which the Arctic aspect is apparent more or less in the molluscan remains they yield, though much the most marked in the earlier of those beds, such as Bridlington, there is nothing, until we go back to the Red Crag, with which we can connect it in point of age; and then the evidence of connexion is more inferential than direct, because the geographical connexion of the St. Erth bed is clearly more in the direction of the Pliocene of Southern Europe than of the Pliocene of the area washed by the North Sea. One only of the six St. Erth *Nassæ*, viz. *N. granulata* (or *granifera*), is known from the North-Sea Crag, while three of them seem to me identical with Italian Pliocene forms, and the other two belong to a group (the *mutabilis* group) that is peculiar to the south of Europe, both fossil and recent.

Our knowledge of the Normandy-Crag Mollusca is very limited. Of the specimens from the older part of it, the "Conglomerat à Térébratules" (which in its physical character, and in the species of Bryozoa it yields, seems to have the closest affinity with the Coralline Crag), scarce anything but a few casts of indeterminate species are given by Messrs Vieillard and Dollfus, in their "Etude Géologique

* Quart. Journ. Geol. Soc. vol. xxxviii. p. 732.

sur les Terrains Crétacés et Tertiaires du Cotentin;" and among these there is nothing but *Ostrea edulis* and undetermined single species of *Turritella*, *Cerithium*, and *Nucula*, that even generically occur in the St. Erth deposit. There is a more copious list given in the Geological Magazine for May 1872, by Mr. Alfred Bell, from an examination of the collection made by Sir Charles Lyell from the Cotentin Crag, supplemented by some additions from the authority of M. Hébert; but there is nothing in that paper to show whether these represent this older "Conglomerat à Térébratules," or the newer "Marnes à Nassa," and I suspect that Mollusca from both of those beds are mixed up in that list. From these "Marnes à Nassa," MM. Vieillard and Dollfus give a more copious list; but there is little in common between it and the list from St. Erth. None of the St. Erth *Nassæ*, save perhaps *N. granulata*, nor any of the more remarkable St. Erth shells, are among the species mentioned. Only *Ringicula buccinea*, *Calyptræa chinensis*, *Natica millepunctata*, *Cerithium reticulatum* (*scaber*), *Lucina borealis*, *Ostrea edulis*, and possibly *Natica sordida* as *N. proxima*, *Nassa granulata*, *Turritella triplicata* as *Turritella vermicularis*, and *Pectunculus glycimeris* as *Pectunculus* (species), out of the many St. Erth shells can be recognized in it; and though there are two or three Mediterranean species among them not known in the North-Sea Pliocene, yet the whole fauna is essentially the same as the fauna of that Pliocene, and but subordinately connected with the Pliocene of Southern France or of Italy, which, so far as the evidence serves to show, is just the reverse of the St. Erth fauna.

We must, as the case at present stands, infer either that Cornwall and Normandy, near as they are to each other, were at the time of the St. Erth deposit separated by a land barrier; or else that even the "Marnes à Nassa" are older, and that the deposit of the Normandy Crag had ceased before the St. Erth deposit began. My present impression is that the latter was the case, for the fauna of the "Marnes à Nassa" seems to me to indicate an age intermediate between the Coralline and Red Crags, rather than (as it has been supposed) a Red Crag age.

Of whatever age the St. Erth bed may precisely be, however, it seems pretty clear that at the time of its deposition there was no communication from the South Atlantic and Mediterranean to the North Sea, except round the North of Scotland; so that such of the southern species as had not been denizens of the North Sea during the Older Pliocene, and so lingered on there into the Newer Pliocene of the Red Crag, were prevented by the differences of nine degrees of latitude between Cornwall and the North of Scotland, and the consequent refrigeration northwards of the marine climate, from getting round into the North Sea.

A change of conditions evidently took place during the formation of the deposit, by which the blue fossiliferous clay was succeeded gradually by a more tenacious yellow clay, which seems to be destitute of molluscan remains, save some unrecognizable fragments of a bivalve; and it is possible that this, and the disappearance of the Mollusca

(which were evidently denizens of a warmer sea than that which now washes the shore of Cornwall), may have been due to the changes consequent on the incoming of the major glaciation.

The fossiliferous clay is of a nature difficult to work for extraction of shells, and the occurrence of specimens, even to the smallest and most unrecognizable fragments, is, except in the case of one or two species, unfrequent; but by the cooperation of Mr. Cornish and the Vicar of St. Erth, I am having consignments of it forwarded me, by which I hope to extract a more extensive collection of the Mollusca of this deposit, by which the inferences as to its age and relation to other deposits may possibly be modified. Eventually I hope to be able to figure and describe these Mollusca.

Mr. Robert Bell has aided me most materially in searching the collections, recent and fossil, in the British Museum for anything that would throw the light of identity on the more obscure, and on the apparently new forms that the deposit has yielded (which my invalid condition precluded me from doing myself), as well as by his own Recent and Pliocene collections, and knowledge of Recent and Pliocene Mollusca. The publication in 1882 of the third part of Prof. Bellardi's Mollusca of the Tertiaries of Piedmont and Liguria containing the very numerous fossil forms of the genus *Nassa* * that occur in these Tertiaries has been very opportune. Dr. J. Gwyn Jeffreys has also had most of the shells before him for examination, from me; and for his aid in the determination of some of the very minute species, I have to express my thanks.

Angular stones occur occasionally in the clay along with the shells, but I have not met with one more than 3 inches long or more than between 2 and 3 cubic inches in solid dimensions, and they are mostly very much smaller than this. With the exception of some which do not exceed the size of a swan-shot, I have only met with one rounded pebble, about the size of a filbert. The average quantity of the angular fragments, so far as I have encountered them, is about 1 lb. to 1 cwt. of the clay. They seem to indicate that, notwithstanding the southern character of the Mollusca, ice must have drifted over the strait during winter, but I have not detected any glacial striæ in the fragments.

* In connexion with the age of the St. Erth bed, as affected by the proportion of forms in it not known living, it is proper to point out that the proportion of *Nassæ* not known living is quite a fallacious guide; for while of Miocene and Pliocene Mollusca, other than this genus, more than half the Miocene and three fourths of the Pliocene are known living, Prof. Bellardi, in this work, figures, or describes, forms of *Nassa* (of which more than two thirds are ranked as species), to the number of 145 from the Middle, 130 from the Upper Miocene, 61 from the Lower, and 64 from the Upper Pliocene of Italy. Of these he regards none of the Lower, and but one of the Upper Miocene, 4 of the Lower, and 5 of the Upper Pliocene as living species,—the living species, 5 in all, being *N. mutabilis*, Linné, in 3 vars.; *N. gibbosula*, Linné, 3 vars.; *N. reticulata*, Linné, in 2 vars.; *N. incrassata*, Müller, in 4 vars.; and *N. semistriata*, Brocc., in 4 vars.

Discussion.

Dr. Gwyn Jeffreys expressed his regret that the author of this important communication was prevented by illness from being present at the meeting, and said that the paper exhibited indications of the great energy possessed by the author notwithstanding his bad state of health. Great credit was also due to Mr. Robert Bell for his share of the work. After careful examination Dr. Jeffreys recognized 50 species among the fossils obtained from the deposit at St. Erth; but from the number given by Mr. Wood he deducted 5 for duplicates, and one which he thought was not a mollusk. There were thus 44 or 45 species, out of which 11 or 12 are recent and 33 or 34 extinct. Of the latter 11 only are known to him from Tertiary deposits, 4 being of Miocene age, and all of them Pliocene. 22 species were unknown to him either as Tertiary or recent. For the accurate determination of the species, the collection, when more complete, would have to be critically compared with recent forms, and the necessary allowance made for that slight divergence which was always observable in the shells of species whose existence extended over a long period of time. Dr. Jeffreys thought that the author had not quite sufficient knowledge of recent Mollusca for his determinations to be thoroughly accurate. The list of shells needs a careful re-comparison with the species contained in the Tertiary collections of Europe.

He further remarked that no deposits of Glacial age have hitherto been found in the south of England. He was not clear whether the St. Erth deposit was of Older Pliocene or possibly of Upper Miocene age. *Nassa serrata*, Brocchi, was one of the few species in the list identical with Crag forms, namely *Buccinum reticosum* of Sowerby. The deposit did not seem to him to be connected with any Crag bed. A bed near Antibes, in the South of France, seemed to him to resemble the St. Erth deposit in many of its characters, and the Mollusca of these two deposits should be critically compared.

Prof. Prestwich said that this discovery of Mr. Searles Wood was the most interesting that had been made upon the southern coast of England for many years. It was the first clear evidence from fossils of a depression in Cornwall since Palæozoic times, as the beds near St. Austell contain no organic remains. The high- and low-level beaches of Jersey and Guernsey are also unfossiliferous. He felt the same difficulty as Mr. Wood in correlating the beds in Brittany. The beds at Bosq d'Aubigny, in Normandy, present many points of analogy with those of St. Erth. There is the same preponderance of Subapennine and Mediterranean species, with many Crag fossils, but the species are different.

Mr. Etheridge thought that the author had been rather hurried in drawing his conclusions, and that more stratigraphical and geographical evidence as to the distribution of the bed, and a careful survey of the neighbouring coast were requisite. He said that Mr. Solly had tried to make out the succession of the clays, and

Mr. Bell had done much with the fossils, but no doubt many more fossils were yet to be found, and the Foraminifera, which are numerous, had not been determined. For his own part, he had much faith in Foraminifera, when properly determined, as a means of settling the age of such deposits.

Prof. T. M'K. Hughes inquired whether the fossils had been carefully collected from both the yellow and the blue clay, and where exactly the change in the fauna, which had been mentioned, occurred. The yellow clay, he thought, must be only the oxidized condition of the blue clay. He asked further what were the relations of the blue clay to the underlying sand, and of the sand to the beds below it.

Mr. Solly said that the section shown in the diagram was merely diagrammatic; it was not that of any one pit, but made up from several pits. The junction of the sand with the blue clay is not seen. He explained the relations of the different beds as seen.

Mr. Robert Bell explained that the blue clay varied in character, the lower part being unfossiliferous, while the upper part contains all the fossils. He objected to the deposit being called Miocene, and, from the evidence of some of the shells, regarded it as nearly of Crag age. The sand shown in the diagram was said to surround the clay.

10. Note *on a* Section *near* Llanberis.

By Professor A. H. Green, M.A., F.G.S. (Read December 3, 1884.)

Those geologists who hold that the quartz-felsites between Llanberis and Caernarvon are of Pre-Cambrian age, rest their belief mainly on the fact that the conglomerate which they take to be the base of the Cambrian rocks in that district contains numerous pebbles of this felsite. It would be very desirable to have this inference confirmed by direct evidence of stratigraphical unconformity between the two rocks; but I do not know that any one has been able to point to a section where that conglomerate is seen actually resting on the felsite, and where there is an unconformity at the junction. The section which I wish to describe, and which seems to have escaped the notice of the geologists who have from time to time during the last few years reexamined the district, does show the conglomerate resting with the most marked unconformity on a lower group of rocks; and it is for this reason that I call attention to it. I saw the section first in the summer of 1880, and visited it again during the summer of the present year.

The section is found in one of the cuttings of the railway which runs from the Dinorwig quarries along the north-eastern shore of Llyn Padarn; to show its position with respect to the adjoining rocks, I have plotted, in fig. 1, the section along the railway from some distance on either side of it. We start at the south-eastern end in the bottom beds of the slaty series which here forms the middle member of the Harlech and Llanberis * group, and which is worked in the Dinorwig quarries; beneath this come alternations of slates and grits, between 800 and 900 feet thick, dipping steadily in a south-easterly direction at about 60°. Beyond these, a bed of massive grit comes up; it shows no lines of bedding, but the overlying grits are well bedded and flatten and bend over it to the north-west. Then follows conglomerate and breccia, with the usual character of the basement conglomerate of the Harlech and Llanberis beds. The junction of the massive grit with the conglomerate is nearly vertical, and is very likely a fault.

A little further on, the beds roll over and the conglomerate is overlain by grits dipping to the north-west. We then come to the part of the section lying between the points P and Q, to which I wish to call special attention (enlarged in fig. 2, p. 76). The first rock we encounter, marked A, is fissile and slaty; it consists of a number of thin layers, nearly vertical and all lying parallel to one another, varying in colour and composition, some greenish and sandy, others smoother, very flaky, and somewhat soapy. The question arises, Are these layers beds or cleavage-laminæ? The marked difference between them in colour and composition is strongly in favour of their being beds. Next comes a band marked B. The matrix of this rock is grey, or greenish

* To avoid the ambiguity which attaches to the word "Cambrian," I use this name for the beds called Cambrian by the Geological Survey.

grey, with very smooth fracture not unlike that of the felsite, but the rock is soft enough to be scratched by the knife and slightly soapy to the touch; it contains many blebs of quartz and fragments of other minerals and rocks, all very much altered; it is very decidedly, but rudely, cleaved, and the cleavage-planes bend in a wavy way round the fragments. The surfaces bounding this band of rock are parallel to the laminæ of the rock A. The rock C, that comes next, is a breccia with a dark grey matrix; the fragments are all flattened and lie with their flat faces in the same direction; there is a rude wavy cleavage with a tendency to bend round the fragments. We have here then three bands of rock, all differing in lithological character and separated from one another by parallel and nearly vertical planes; one of these bands (A) is made up of numerous laminæ, each differing from its neighbour in composition, and these laminæ are all parallel to one another and to the planes which separate A from B, and B from C. These facts, it seems to me, admit of only one interpretation. The rocks are bedded and in a nearly vertical position; there is cleavage as well, and the cleavage and bedding coincide; but while the flakiness of the rocks B and C is due to rude cleavage, the plane separating these rocks from one another, the plane separating B from A, and the planes of lamination in A must, I think, be planes of bedding.

These flaky rocks occupy the whole face of the cutting for a space of about twenty yards, but towards the north-west end a capping of conglomerate comes on above them. The junction slopes down to the

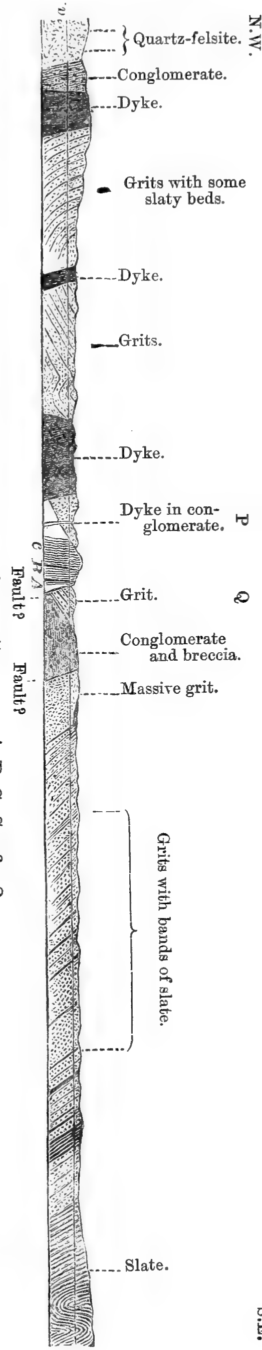
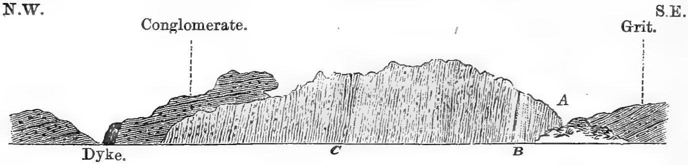


Fig. 1.—*Section along a part of the Dinorwig Railway, on the North-east Side of Llyn Padarn.* (Scale about 400 feet to 1 inch.)

a–b. Level of the railway. A, B, C. See fig. 2.

north-west, and the conglomerate creeps over the flaky rocks with a rapidly increasing thickness till it comes down to the level of the railway. This conglomerate has the same character as that seen on the other side of the flaky rocks; it contains a few fine slaty bands which give the dip and show that the beds are running down at moderate angles to the north-west. I could not see the actual junction of the flaky rocks with the grits to the south-east of them, but I traced the two to within a few feet of one another, and it seemed likely that they were separated by a fault.

Fig. 2.—*Enlarged Section between the points* P *and* Q *in fig.* 1.

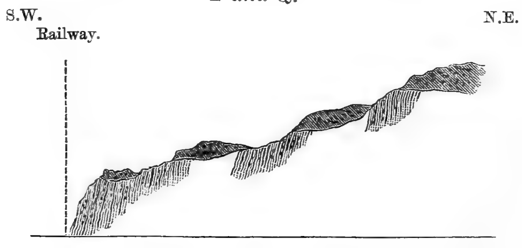


A. Fissile flaky rock. B. Greenish-grey fragmental rock.
C. Grey breccia.

There seems to me no room for doubt that in this section we see the top of a projecting boss of a group of rocks underlying the Harlech and Llanberis beds, and that the conglomerate rests on these rocks with the strongest possible unconformity.

Further proof of the unconformity is found when we examine the hill side on the north-east of the railway. For some way up (fig. 3)

Fig. 3.—*Section at right angles to the Railway, between the points* P *and* Q.



we find the fissile rocks peeping out every here and there in gullies and other depressions, with the conglomerate lying upon their edges.

I am afraid it may be thought that I have been unnecessarily prolix in my account of this small section, and I certainly should not have thought that there was any need to give, at such length, the evidence for what seems to myself a very simple matter, if it had not been for the following circumstance. I believe that the section just described is the one figured by Sir A. Ramsay in the Survey Memoir on North Wales (pp. 178, 179, figs. 62 and 63), and he there gives a reading of it very different from my own. He calls

attention to the strong cleavage and the flattening of the fragments in the rocks B and C, and he shows these rocks as vertical on the south-east, so far agreeing with myself; but on the north-west he makes the beds flatten, and draws across the flaky rocks lines of bedding sloping at a moderate angle to the north-west, running in fact parallel to the junction of the conglomerate and the flaky rocks. In short he makes no distinction between the flaky breccias and the conglomerate, but looks upon the former as a part* of the latter somewhat altered in character by intense cleavage. It is with no small amount of diffidence and regret that I feel bound to differ from my old honoured master; but I feel sure that the bedding of the flaky breccias is nearly vertical from one end of the exposure to the other. Further, these breccias prove on examination to differ totally from the conglomerate, and, indeed, from any part of the Harlech and Llanberis group, in their character and origin. I cannot therefore accept his interpretation.

To this point, the nature and origin of the flaky breccias, we next come. Under the microscope, with a power of 40 diameters, the matrix of C is seen to be fine dust full of minute plates and films of a micaceous mineral that, under crossed nicols, is golden yellow shot with green and red. Among the fragments are a few blebs of quartz, bits of kaolinized felspar, a fragment very like a bit of quartz-felsite, and several pieces of dark vesicular scoriæ; but the larger part of the fragments are not exactly determinable on account of the alteration they have undergone; they remind one of basic crystalline rocks that have been very thoroughly serpentinized and viriditized, and in part converted into calcite.

The matrix of B is generally similar to that of C, but finer and more uniform in grain; it lies in long wavy bands which bend round the fragments and simulate very closely true fluxion-structure; the fragments are most of them similar to those of C, but not so numerous, and quartz is more abundant; there are a few plates of mica and some bits that remind one of fragments of crystalline schist.

In general character both these rocks are very like rather coarse volcanic tuffs, and the presence of vesicular scoriæ in C is in favour of the view that this is their character. Professor A. Geikie tells me that they are very like some of the tuffs of St. Davids which are classed by Dr. Hicks as Pebidian.

It may be desirable, though perhaps hardly necessary, to point out that the unconformity of this section, strong as it is, does not necessarily indicate any great difference in age between the conglomerate and the breccia on which it lies. These breccias are of volcanic origin, and the irregular and restricted upheavals and disturbances, which are always liable to occur where volcanic activity is going on, are quite competent to bring about unconformities

* "Part of the conglomerate consists of slaty pebbles in a slaty matrix, the whole being affected by slaty cleavage, remarkable on account of the pebbles being elongated in the direction of the cleavage-lines." (Geol. of N. Wales, p. 179.)

quite as marked as those of the present section, which are purely local and would be found to disappear if we were able to trace the junction of the two groups of rocks over a large area.

The remainder of the section along the railway explains itself; but I may mention that the nature of the junction between the conglomerate and quartz-felsite at the north-western end is doubtful; it may be a fault, but there is nothing whatever to show whether it is or not. The matrix of the conglomerate is very instructive; it is mashed up and reaggregated felsite, and it has been so little altered by the breaking-up, and has been so firmly bound together again, that it bears a very close, though of course superficial, resemblance to the felsite itself. This resemblance does not altogether disappear even under the microscope. The pressure which the conglomerate has undergone has squeezed the fine portion of the matrix into wavy flowing bands which bend round the blebs of quartz, so that a structure has been set up in this clastic rock which simulates most closely the fluxion-structure of the felsite itself. The quartz crystals and blebs, too, of the conglomerate have often been so little damaged during the disintegration of the felsite that they still retain exactly the same appearance as in this latter rock. Indeed if we cut a slice from the conglomerate so as to steer clear of pebbles, it would very frequently be undistinguishable under low powers from a slice cut from the felsite; it is not till they are magnified some 300 diameters that the difference between the two comes out.

Discussion.

Prof. T. M'K. Hughes gave an explanation of the section, and indicated some details showing what he regarded as the behaviour of the beds. If older beds come up at the point indicated, they would probably be Pebidian. He stated that the section was very complicated, and the particular portion described by the author does not, perhaps, carry with it the same conviction that other sections do. The conglomerates are made up of the underlying rock to such an extent that it is sometimes difficult to distinguish the one from the other, where both are squeezed, faulted, and contorted. The N.E. and S.W. section, as shown, did not explain itself except with the intervention of faults. The principal section appeared to be correct in the main; but perhaps some modification might be necessary in details.

Dr. Hicks said that he had very little to add to Prof. Hughes's remarks. He also would not have selected this section as the best example of the unconformity between the Cambrian and Pre-Cambrian in this area. The section, however, was an important one, as it showed that the Pre-Cambrian rocks extend further towards Snowdon than had previously been ascertained. At the N.W. end of the section there were clear indications of unconformity, but masked partially by faults. From the present evidence it is clear that an unconformity does exist. The important point to be

remembered is that the cleavage in Pre-Cambrian beds is of earlier date than that occurring in the Harlech and Llanberis series, as may be shown by an examination of the fragments of the former in the latter. These fragments, as he had often stated, showed the original cleavage as well as the effects of subsequent crushing.

Mr. Rutley remarked that he believed rocks of the class described were not uncommon, as, for example, on the flanks of Snowdon between Llyn Llydaw and Llyn Teyrn, having cleavage coincident with the bedding. He thought the quartz-felsite described by Prof. Bonney as old rhyolite might be expected to reappear, instead of the beds beneath the breccia, and wished for definite information concerning the character and position of the lower series of rocks between the quartz-felsite and the fissile breccias exhibited.

Prof. Hughes explained that the newer series being absolutely unconformable to the older, the different beds of the latter appeared below the base of the newer series successively, and the Pebidian might well come in the spot indicated.

The President stated that he knew the section described, which he had visited with Prof. Hughes. The junction of the conglomerate and felsite was very obscure. In the part between P and Q in the diagram the lower part of the conglomerate, as he had considered it to be, has a peculiar appearance, and is no doubt the rock described by Prof. Green as a breccia. At all events the section is not so clear in nature as in the diagram. The section at Moel Tryfaen is similar. On the south-west of Llyn Padarn one meets with a puzzle of something the same kind,—quartz-felsite, then conglomerate, then (apparently) cleaved felsite, then conglomerate again; and it is not clear whether the conglomerate rests unconformably on the felsite, or whether there is a series of faults complicated by dykes. Professor Green's reading of the section might be the correct one, but he felt very doubtful.

11. *On some* West Indian Phosphates. By George Hughes, Esq., F.C.S. Communicated by W. T. Blanford, Esq., LL.D., F.R.S., Sec. G.S. (Read November 17, 1884.)

From the specimens of West Indian phosphates and coral I have the privilege of bringing under your notice, I desire to direct your attention to the fact that, under certain conditions, it is possible for coral-stone to be converted into phosphate of lime. Dana, in his work on Corals and Coral-islands, speaking about the formation of Howland's Island, says: "Some interesting pseudomorphs occur buried in the guano of this island. Coral fragments of various species were found that had long been covered up under the deposit, and in some of which the carbonic acid had been almost entirely replaced by phosphoric acid. In such I have found 70 per cent. of phosphate of lime. In many others the change was only partial, and on breaking some of these, in the centre was usually found a nucleus or core of coral still retaining its original hardness and composition, while the external parts had been changed from carbonate to phosphate, which, though soft and friable, still preserved the structure and appearance of the coral."

My attention was first directed to this fact in the island of Barbuda, where I found a small vein, rich in phosphate of lime, starting from the bottom of a cave in the face of a coral cliff. The earth in this cave consisted of phosphatic guano formed from excrement of bats, and similar in composition to the earth that is generally found in tropical caves. The water draining from this guano-earth must have contained phosphoric acid in solution, probably as phosphate of potash, soda, and ammonia, and subsequently, passing through the coral, caused the remarkable change in the composition of the rock with which it came in contact. The specimen of stone taken from this particular vein, shows that, whilst one portion remains white and consists of carbonate of lime, the other portion of the same stone that entered into and formed part of the vein is coloured yellow from organic matter, and the carbonic acid has been almost entirely replaced by phosphoric acid.

It is, however, to the deposit found in the island of Aruba that I desire to draw your special attention, because there this process of phosphatizing the coral has been in operation on a most extensive scale. The deposit is estimated to contain not less than 500,000 tons; it occurs at the extreme point or cape of a peninsula of coral; the headland is called Sierra Colorado (or red hill), and rises about 300 feet above the level of the sea and about 200 feet above the level of the coral that connects it with the island of Aruba. My opinion is, that when this hill existed as a small island, or "cay," and the coral reef between it and the then main island of Aruba was submerged, it was the resort of sea-fowl, and their excrement, like the bat-guano, containing soluble phosphates, caused the change in the rock upon which it was deposited. There is no trace left of

the phosphatic guano upon the surface; but the solid rock is now rich phosphate. From these specimens of the phosphatized coral it will be seen how complete has been the change, and at the same time how perfectly the coral has retained its structure.

These specimens of phosphatized coral yield from 78 to 80 per cent. of phosphate of lime, and, so far as the deposit has been shipped as yet, the cargoes have tested over 76 per cent. of phosphate.

Analysis of a Sample of Aruba Phosphate.

Moisture	·62	
Water of combination and traces of organic matter	2·91	
Phosphoric acid	35·70	(equal to tribasic phosphate
Lime	46·37	of lime .... 77·93)
Oxide of iron	1·80	
Alumina	2·95	
Carbonic acid	1·53	(equal to carbonate of lime... 3·54)
Sulphuric acid	1·55	
Fluorine &c.	4·22	
Silica	2·35	
	100·00	

Other deposits of phosphates found in the West Indies owe their origin to direct marine deposit of bone, as, for instance, that of Curaçao. In the next island to Curaçao (Bonaire) I have seen the coral over an area of two miles to contain fossil bones and teeth scattered in all directions. The specimens I have the pleasure of showing you from that island give a very good idea of how these bones occur; and had they been deposited in one spot, as in Curaçao, we should have been able to have worked a good deposit.

Discussion.

Mr. B. B. Woodward asked if in the West Indies the same conditions were found as in some of the islands of the South Pacific, namely, the carrying-down of phosphates into the mass of the coral-reef, and the subsequent removal of the carbonate of lime leading to the formation of casts of corals in the phosphate of lime.

Prof. T. Rupert Jones asked if there are any guano-islands in the West Indies now.

Mr. Hudleston asked if the facts observed threw any light on the formation of the phosphatic layers in the Cretaceous rocks.

The Author replied to Mr. Woodward that he had not observed casts of corals in phosphates found in the West Indies. To Prof. T. Rupert Jones, that guano-deposits are still in course of formation, as, for example, in the Monks Islands near Aruba. The rain, however, dissolves out the soluble phosphates, which are lost, as the rocks on which these deposits occur are of a siliceous nature. The insoluble portion of the guano forms a crust upon the rock. To Mr. Hudleston, that this replacement of carbonic acid by phosphoric acid might throw light upon the formation of phosphatic layers in the Cretaceous rocks.

12. *On the* Lower Eocene Plant-beds *of the* Basaltic Formation *of* Ulster. By J. Starkie Gardner, Esq., F.L.S., F.G.S. (Read December 3, 1884.)

The general features of the basaltic district of Ireland have been too frequently described to need more than a few introductory words here *. It is situated in the N.E. of Ireland, and forms a plateau with steep escarpments on every side, except in the direction of Lough Neagh. The formation rests upon a very uneven surface, and the thickness of the lowest of the three divisions into which it has been classified is thus very variable. It is described by Hull as "silicated felspathic trachytes, porphyry, pearlstone, pitchstone." But a good deal of the lava resting upon the Chalk appears outwardly to be amorphous trap. The second division contains all the plant-beds hitherto found in the basaltic formation in Ireland, with the possible exception of those of Lough Neagh. The third is composed of solid sheets of columnar and amorphous basalt. The greatest total thickness observed in Ireland is at Sleamish, a mountain 1437 feet high, all that is visible (at least 1100 or 1200 feet) being composed entirely of basalt. These basalts have been eroded on a colossal scale, for the valleys are scooped out of solid horizontal sheets, as pointed out by Conybeare to this Society so long ago as 1816 †. They seem to have formed almost the southern limit of a formation which once stretched continuously to Iceland, and to what thickness they were originally erupted can never be known; but the upper or columnar basalt series, now only 400 or 500 feet thick in Antrim, is believed to expand to the immense total of from 3000 to 4000 feet in Mull, only some 70 miles distant. One of their most characteristic features, as in Iceland, is the relative rarity of dykes. When present their prevailing trend seems to be S.E. to N.W. I believe the idea that any traces of necks or craters remain, through which such masses could have been erupted, though once strongly advocated ‡, is now abandoned, and the theory that at least the upper series welled up through fissures, represented in part by the four gigantic dykes seen on the north coast, will, perhaps, be more generally acceptable.

The middle horizon, in which most, if not all, of the sedimentary deposits containing plants occur, marks a very considerable interval of time during which the slow disintegration of the basalts permitted the formation of iron-ores to a thickness of 40 or 50 feet and also of great masses of lignite. The sedimentary deposits of Glenarm and of Ballypalady, at least, show the passage of larger bodies of swiftly-flowing water, and were formed in the bed of a river. The lignites

* Hull, Phys. Geol. & Geogr. Ireland, chapter iii.; Kinahan, Geology of Ireland, 1878; Portlock's Report on Londonderry and Tyrone; &c.

† Geol. Trans. vol. iii.; Berger on the Geological Features of North-east Ireland, p. 127.

‡ Hull, Phys. Geol. & Geogr. Ireland, 1878, chapter iii.

show that this was bordered in places by marshy or boggy land. All the physical data combine to prove how vast the antiquity of this part of the formation must be; but as I have recently discussed these at some length elsewhere (and those interested can follow my arguments in the 'Report of the Belfast Naturalists' Field-Club' for the year 1884), I do not propose at present to allude to them further. Conclusive, however, as the inferences deduced from physical data appeared, I am able, through still more recent investigations, to set aside the whole of this evidence, and to demonstrate on simple palæontological data that the plant-beds are actually very low down in the Eocene series. All are aware how universally they have hitherto been regarded as Miocene. Nothing, indeed, in the progress of geology appears more remarkable than the almost complete unanimity with which their age has been accepted, when the character of the evidence is examined. Of the many distinguished writers on the basalts of Ireland and Scotland, not one has called it in question; and Prof. Hull, for instance, almost apologetically ventures to speak of the lowest trachyte or porphyry of Sandy Brae as "possibly belonging to the latter part of the Eocene series;" "at any rate, such is the contrast to the overlying sheets of basalt of known Miocene age, that I am constrained to infer a considerable lapse of time between their respective eruptions"*.

As I propose to review this evidence at length elsewhere, I do not think it necessary to do more than glance at it now. The first description of any inter-basaltic plants was communicated to this Society by Edward Forbes in 1851 †. Our knowledge of Tertiary plants was very meagre thirty-three years ago, and he was only able to hazard the opinion that, judged by the then state of our knowledge, they were "decidedly Tertiary," and "most probably" Miocene. Heer ‡ subsequently claimed two of them as Miocene forms; but the first is merely a yew-like coniferous twig, probably a *Taxus*, that might be of any age; and the second a dicotyledonous leaf which finds its parallel equally in the Cretaceous and in the old Eocene of Sézanne. Many of the Mull plants are also found at Atanekerdluk; but the age of these beds has been settled in precisely the same perfunctory manner as in the instances we are discussing. It occurred to somebody that the Antrim and the Mull plants must be of the same age; but the only notice I can find of any actual comparison of them is by Baily §, whose conclusion that they differed as a group tells in an entirely opposite sense. I am, in fact, personally aware, so far, only of one plant in common; and this is not only rather doubtful, but was discovered at Mull only three or four years ago, and is not yet published ||, nor has it been made use of by any one for comparison. The Irish plants are all from below the columnar basalts and are very considerably older than the Mull plants, which

* Hull, Phys. Geol. & Geogr. Ireland, 1878, chapter iii.
† Quart. Journ. Geol. Soc. vol. vii. (1851), p. 103.
‡ Lyell's 'Elements of Geology,' 6th edit. 1865, pp. 261, 262.
§ Quart. Journ. Geol. Soc. vol. xxv. (1869), p. 360.
|| Since published in the issue of the Palæontographical Society for 1884.

occur among the columnar series. Now there is only one flora, whose age is stratigraphically ascertained, that the Irish plants resemble; and this is the Heersian flora of Gelinden, so low down in the Eocene that we have no representatives of it in England. The resemblance is not superficial, but, as I intend to demonstrate on another occasion, fundamental. Already in the Mull beds, and equally in our oldest English Eocene floras from below the London Clay, the Heersian characteristics have disappeared. On the other hand, these Irish floras have not one single element in common with any of ascertained Miocene age. In this communication these must remain merely bald statements requiring corroboration; but I intend, as I have said, to go so fully into the matter at a future time, that it would be useless to do so imperfectly now.

I will now proceed to describe the actual localities whence the plants are obtained, so that the conditions under which they have been preserved may be realized. The Ballypalady locality has been described to this Society, and I therefore content myself with a reference to it almost confined to points previously overlooked or where my interpretation differs. The Glenarm mine has only been described at second-hand and from recollection, owing to its having been inaccessible for many years, and no account of it has been laid before this Society. The Ballantoy beds have only yielded an insignificant number of plants, and are therefore not of very great interest. The Lough-Neagh beds, on the contrary, are of such vast extent and thickness and so little is known regarding them, that I have thought it well to collect all the actual observations I can find on record likely to assist in determining their age. Hull and Kinahan unite to consider them Pliocene; but it will be seen that some of the older writers agree with members of the Belfast Field Club, especially Messrs. Gray and Swanston, in considering their age to be contemporaneous with the basalt; and this view I do not hesitate to uphold. Finally I have thought it useful to add, for comparison, some notes taken during a two days' visit to Ardtun Head in Mull.

Before going further, I cannot help calling attention to the remarkable support the physiography of this district lends to a theory I have sometimes advocated, namely, that the addition of weight at any given spot causes a depression of the earth's crust in some degree equal to this addition. The basalt forms a high plateau on every side except towards Lough Neagh. Here there is an area of at least 40 square miles of accumulated sediment which has been bored to a depth of 300 feet without bottom, and here only are the basalts dragged down, as it were, to beneath the sea-level. I have further shown that the theory, pushed to one of its logical conclusions, demands a slight uptilting of coast-lines and that cliffs should have an inland dip. A glance at the arrows on the Geological-Survey map shows that the dips are invariably in accordance with this theory, falling away from the sea with every point of the compass demanded by the shore-contours, producing anticlinals on the opposite sides of sea-loughs. Again, though the lofty shore dips inland as usual opposite Rathlin Isle, the strata are exactly reproduced there on a

lower level and with the same dip, a repetition that could only occur through subsidence.

The Ballypalady Leaf-bed.

The beds were first exposed in a small railway-cutting about a mile north of Templepatrick station. A quarry was subsequently opened in them in a ravine a few yards to the south, and has been worked some 200 yards east and west, with a depth of about 25 feet. A massive basalt dyke separates it from the cutting, so that it is impossible to say whether the section on the higher level is an upthrow of the beds seen in the quarry or a higher portion of the series which should be added to its thickness. The total thickness is in any case unknown, as the quarry does not expose the base. The beds are laminated, indurated, ferruginous earth, fine breccias of altered volcanic material, and thin seams of lignite irregularly deposited and somewhat twisted. The prevailing colour is an ochreous brown. The breccias, though coarse, seem wholly free from any mixture of the older rocks, and contain neither flint nor lime derived from the Chalk.

The plants do not appear to be confined to any particular horizon or patches, but are distributed, in more or less perfect preservation, wherever the matrix happens to be sufficiently compact, and fir-cones are found even in the breccias. The beds have hitherto been supposed to be lacustrine; but the coarseness and brecciated nature of some of the layers, and their irregularity, indicate the bed of a shifting river subject to variations in volume. The width of the deposit cannot be ascertained; but in the cutting about a quarter of a mile to the south the beds seem possibly Geyserian and to have been subjected to great heat. Their horizon has been determined by the Geological Survey at some 600 feet from the base, and 400 feet from the top of the basaltic formation.

Iron-ores, boles, lithomarges, and pisolitic ores are widely distributed through the basalts, for the most part on one horizon, but are destitute of all plant-remains except wood. They are unfortunately nowhere fossiliferous except at Ballypalady; but as the section there is not complete, it may be useful to supplement it with one quoted in the 'Guide to Belfast' by the Naturalists' Field Club, p. 60, at Belumford, Island Magee. Here the pisolitic ore averages about 18 inches thick, the aluminous ore varies up to 5 feet thick, and the lower or lithomarge bed is sometimes found as thick as 40 feet or more.

The Glenarm Leaf-bed.

This bed occurs in the iron-ore and bauxite mine of Libbert*, about a mile in rear of Glenarm, and about 700 feet above the sea-level. The Chalk crops out in the road, and the basalt a little above

* The mine was full of water and quite inaccessible for some years past, until I had it drained and reopened.

it; but the rest of the hill is masked by Boulder-clay. The horizon of the leaf-bed must, however, nearly approximate to that of Ballypalady.

The adit is level, and after piercing about 30 feet of Boulder-clay, reaches a compact sandy clay in which the plant-remains occur. Beneath this is an indurated micaceous sand, the base of which is not exposed, so that its thickness cannot be measured. The miner whom I employed stated that the base was lithomarge, but he did not know how deep down this occurred. The leaf-bed itself occurs at the angle of a cross-cut and does not reappear on the opposite faces; it is bounded on one of the remaining sides by the Boulder-clay, and on the other by a slight downthrow, so that its superficial extent is very limited. The bed is about six feet thick, but well-preserved leaves are confined to about one foot, where the matrix is whiter and more laminated clay. The rest of the bed is greyer and more sandy, and contains dark and ill-defined impressions of leaves, limbs, and trunks of trees, and extends a considerable distance into the mine. Above this is a singular conglomerate of well-rounded pebbles of very hard clay in an equally indurated paste. The surfaces of these pebbles are here and there polished and striated by pressure, and darkened so that they exactly resemble flints to the eye. This conglomerate is succeeded as well as sometimes replaced by coarse quartz-grits, the grains being always cemented by the same paste. These and the grey micaceous sandy clay are at least 30 feet in thickness. The bauxite rests upon this and also contains masses of lignite and lignitized wood. Deeper in the mine it becomes blotched with red and gradually passes into an iron-ore, which also overlies it, and which, with a band of lignite, completes the series of sedimentary deposits up to the basalt. The lower parts of the deposit were undoubtedly formed by running water of some swiftness; but the upper parts (the lignite, the bauxite, and iron-ore) are the results of more tranquil deposition. The bauxite may be the finer residuum from the decomposition of granite, or of basalt, with the iron &c. removed by some natural process; but it is evidently not Geyserian, as the bauxites of France have been surmised to be.

The Ballintoy Leaf-bed.

The leaf-impressions are found in compactly laminated lignite, and the leaves present a somewhat glistening surface in contrast to the dull black of the matrix*. Wood-structure is also well preserved, and can be recognized as coniferous. The lignites are here directly overlain by the basalts, but rest on carbonaceous clay with rootlets in the usual manner. Their thickness appears to vary from 2 to 5 feet; but they are, in places at least, separated into two beds by intervening clay. The beds extend for some distance, and the

* Traill mentions the occurrence of plants in the clay under the lignite, but I have not myself come across any in this position. He places the lignites of Ballintoy at some 30 to 40 feet above the bole.

formation appears to be the most extensive of its kind in Ireland. Ballintoy is on the coast, a little east of the Giants' Causeway. Lignites occur in many other places within the basaltic area, and occasionally present themselves in the escarpments all round its borders. In no other district, however, have any defined leaf-impressions been detected, and their interest is therefore purely stratigraphical. Wood in a very interesting state of preservation is obtained from the neighbourhood of the Causeway. It is very fibrous, of reddish rust-colour, and almost satiny sheen. The whole tissue has been replaced by oxide of iron, leaving every detail of structure in marvellous preservation. Mr. Carruthers kindly examined it with me and concluded that, unlike all the silicified wood we have yet seen from Lough Neagh, it is of pine and not cypress wood. A considerable bed of lignite, stated to be six feet thick, crops out in the grand section above the Causeway, and there are ochreous earths at several horizons; and even so far back as 1836 Nasmyth found what he took to be charred branches of trees in the red hæmatite there*. At a place called Lemeneigh the lignite is overlain by compact reddish earth; and in the not distant bauxite-mine the lignite, five feet thick, is directly overlain by basalt, and rests upon impure bauxite with veins of lignitic matter, then purer bauxite, merging, as at Glenarm, into iron-ore. In the spoil-bank here I found a single impression of a leaf; but though Mr. Swanston and I made every search in the mine, we could not find whence it came. The lignites, iron-ores, and bauxites are here, as elsewhere in Antrim, on practically the same horizon.

The Lough-Neagh Formation.

The lignitic series of Lough Neagh is very considerable, occupying about 180 square miles, including the entire Lough, except the northern shore between Ballyronan and Sandy Bay. It has twice been bored near Anaghmore to a depth of about 260 feet †, at Portmore to 240, and Dernagh to 173 ‡, without having in any of these instances been penetrated. Its total thickness can therefore only be inferred §.

Its composition is similar to that of the Tertiary formation at Bovey, being a mass of alternating white, brown, greenish-blue, and red plastic clays, white and grey sand, with irregular beds of lignite. Judging from the composition of the series it seems probable that it may contain many fossiliferous bands.

The numerous writers upon it agree in placing its stratigraphical position above the Chalk and beneath the Boulder-clay. It is also believed to rest on basalt throughout a great part of its area, but to overlap and rest on the Trias in the direction of Tyrone. The only two points where it appears to have been actually observed resting on

* 'Autobiography of Nasmyth,' by Smiles, 1883.
† Griffith, '2nd Report of Railway Commission,' p. 22.
‡ Hardman, 'Journ. Roy. Geol. Soc. Ireland,' vol. iv. p. 176.
§ Hardman, Expl. Mem. to Sheet 35, Geol. Survey of Ireland, estimates their maximum thickness at not less than 500 feet. Portlock's Report, p. 74.

basalts are in the Ballinderry river (where it is described by Portlock as "alternate layers of sand and imperfect lignite, in fragments 1 to 4 inches thick," 6 feet; blue clay, no depth stated; basalt) and in the Crumlin river* (where it is only 7 feet thick, 3 of which are coarse gravelly matter and 1 foot a bed with shells). Mr. Swanston † and others have shown that in this latter example a drift with fresh-looking shells of *Mytilus edulis* ‡ had been mistaken for the Lough-Neagh beds; while even at Ballinderry the section does not seem to have been accurately observed, and might be in a redeposited mass. There is great probability, however, that a large part of the formation may actually rest upon basalt; but the view embraced by the Geological Survey of Ireland and others, that the entire formation is newer than the latest basalts, seems opposed to the evidence; and the inferences that it is Pliocene, Pleistocene, and even practically the delta-formation of existing rivers, and intimately connected with the present lake, are, to my mind, wholly unwarranted. It may be, as at Bovey, that the beds are in places, however, covered with a recent head. The position and inclination of the beds would lead me to place them low down among the basalts, and in the Glenavy river a mass of basalt all but rests upon them. This relative position has been explained by supposing that the basalt forms an old cliff-line against which the lacustrine beds terminate; but Mr. Swanston has combated these views, and believes the Lough-Neagh Beds to be inter-basaltic. I think the further considerations to be brought forward support his belief.

A question no less vexed, and inseparable from the other, is the age of the celebrated petrified wood of Lough Neagh. The best recorded fact concerning it is the oft-quoted statement of Barton §, a resident and very careful observer, that there was a bank some 12 feet high and 90 feet from the lake, at a place called Aahaness, opposite Ram's Island, where a section was obtained by digging, in 1757, as follows:—"The upper stratum was a bed of red clay, 3 feet deep; the second blue clay, 4 feet; the third black wood, 4 feet, reposing on another stratum of clay. This stratum of wood is of one uniform mass, and is capable of being cut with a spade. Sometimes the wood will not easily break; in that case it requires the aid of some other tool to separate it from the mass; and may, if properly done, afford a block of 200, 300, or 400 lbs., which, being carefully examined, is found to consist more or less of stone"‖. This statement is very explicit and is corroborated by Dr. Scouler, Professor of Mineralogy to the Royal Dublin Society, who adds:—

* Hardman, Geol. Mag. 1876, p. 556.

† Swanston, ibid. 1879, p. 64.

‡ Mr. Swanston adds in a letter to me that the presence of Foraminifera with the *Mytilus* proves these clays to have been of marine origin, and the presence of glaciated pebbles in the "3 feet of coarse gravelly matter" puts them into the drift.

§ Richard Barton, B.D., 'Lectures on L. Neagh,' 1751, pp. 5 & 139, also discussed at length in Portlock's Report, p. 75.

‖ Rev. J. Dubourdieu, 'Statistical Survey of the County of Antrim,' 1812, p. 187, states that the wood is often only partly stone, the brittle wood joining on in one continuous piece.

"but to remove all hesitation on this head, a man was employed in digging till I could obtain both kinds of wood"*. I was personally prepossessed in favour of the theory that the lignites were the true matrix of the silicified wood, as I have met with partially silicified cores to lignitized trunks at Stafholt, in Iceland, and Cushendall, on the Antrim coast. At my suggestion Mr. Swanston, F.G.S., and Mr. Stewart, F.L.S., both most able observers and much interested in the question, visited Lough Neagh on the 17th November last, and were fortunate enough to obtain evidence which I think it must be admitted sets the question at rest†. Their observations are as follows:—

"Near the ferry across to Rams Island, on the level fringe at margin of the lake, a shallow pit has been sunk, and under about 18 inches of surface-gravel a compact bed of lignite has been struck, and several tons of it thrown out. The material is mostly woody, showing a distinct structure, and seems to have been a deposit of broken drift-wood. Mixed with it irregularly is a good deal of vegetable matter greatly broken up. Twigs can be identified in it, but no leaf-form, although from its flaky character it would seem to be mainly made up of decayed leaves. We became greatly interested; and on asking the farmer whether he had found any petrified wood in it, he told us that he had carted some of the lignite to his house for burning, and that the heart of the largest piece turned out to be stone, which he kept, and he was good enough to go with us to the farmstead and give it to us. It was a piece of veritably silicified wood. On examining the heap he had carted, I came on another piece, possibly a fragment of the piece that had been burned, leaving no doubt as to where they came from. The pit has only been sunk to a depth of 4 feet, the lignite being compact and undisturbed, but enclosing small patches of white plastic clay." Mr. Swanston further observes that Barton's description is remarkably exact; for after baling the water out of the pit, he set to work with a spade and dug into the mass. It required great efforts to force the blade of the spade to its full depth into it, as it was not of uniform density, the wood being hard and the other vegetable matter more yielding. The lignite appeared to dip towards the Lough 10° or 15° N. or N.W. The lignites are also cut into at another point north of the Glenavy river, but the spot is at the present winter-season inaccessible owing to the high level of the water. It seems tolerably evident that the silicifying process only takes place where the lignite is of great thickness and the trunks large and compact. The wood is found most abundantly at Glenavy, where these conditions conspicuously exist, as proved by records of borings in the immediate vicinity. Thus Donald Stewart‡, employed by the Royal Dublin Society, says that at Portmore "they bored through two beds of coal, or what is called black wood, 25 feet thick each, and a third 9 feet thick and 80 yards deep; they bored 18 inches into a 4-feet stratum, having

* Journal Geol. Soc. Dublin, vol. i. p. 235.
† Letter from W. S. Swanston, 18th November, 1884.
‡ Scouler, *l. c.* p. 236.

no more rods to go deeper." A boring at Sandy Bay gave, according to Griffiths * :—

	ft.	in.
Blue clay	10	0
Black lignite mixed with blue clay	25	0
Clay	2	6
Black lignite	20	0
Clay	4	0
Black lignite	15	0
	76	6

The area on the Lough over which silicified wood is found extends from Dungannon to Glenavy, a distance of 20 miles. Mr. Gray, of Belfast, has found petrified wood from the drift at Coleraine, taken from a well in the Boulder-clay, 40 miles northward from the mouth of the Crumlin river. Also from the Boulder-clay in a deep cutting at the back of the site for a manse at Cullybackey, 20 miles, and from a cutting in the Boulder-clay for a road between Randalstone and Toome, 10 miles north of the mouth of the Crumlin. On the south side Mr. Gray has only observed it in the drift-gravels within the Maze race-course, 12 miles E. by S. from the same point.

Lawrencetown †, where siliceous lignite has been found in trap, is 17 miles south of the above point. Mr. Gray also calls attention to the fact that lignite like that of Lough Neagh crops out at Dundrod, half way between Crumlin and Belfast ‡. These are outliers, and interesting as showing the extent of the deposit before it was denuded. It is hardly possible for the silicified wood to have travelled north during the Glacial Epoch unless the physical features of the country were completely reversed; and I believe it is a well-established fact that the materials in the Boulder-clay are derived from the north; and, if such be actually the case, there is no escape from the conclusion that the Lough-Neagh beds, or beds similar to them, once had a greater extension by at least 40 miles in a northerly direction and have since been entirely swept away. The view of their former greater extension is further supported by the fact that at Dernagh, parish of Clonor, *not far from the boundary of the deposit*, the beds were not penetrated through by a bore 173 feet deep §.

* Portlock's Report, p. 167.

† In the Proc. Belfast Naturalists' Field Club, 10th Annual Report, 1873, p. 39, Mr. Gray described "the occurrence of silicified wood in the basalt at Lawrencetown, where there is a bed of lignite in the basalt about 30 feet below the surface, and in this lignite there are layers of wood charged with siliceous matter, and resembling the wood erroneously supposed to be petrified by the waters of Lough Neagh. The latter is often found quite hard outside; but when broken, portions of the inside are quite soft and fibrous, like lignite, and pass from soft wood into compact stone, the semisiliceous portions being almost identical with the hard portions of the Lawerencetown lignite." This fact seemed to the author to supply the connecting link between the silicified woods and the basalts described by Portlock.

‡ The above facts, communicated to me by Mr. Gray, have not previously been published in this definite form.

§ Hardman, Journ. Roy. Geol. Soc. Ireland, vol. iv. p. 176.

To set against these positively recorded observations, there is only the opinion that the wood *may* have been derived from beds included among the basalts which *might* be found *in situ*; but the only wood hitherto so found at all resembling that of Lough Neagh is in the state of oxide of iron, and belongs to *Pinus*, while the whole of a large series of Lough-Neagh woods examined with me by Mr. Carruthers is Cupressineous. The evidence, fairly weighed, seems altogether in favour of the interbasaltic age of the Lough-Neagh beds; and my own opinion now is that they are of much the same age as the Ballypalady and other fluviatile deposits to the north, and that they will be found to continue under some of the lavas. A thorough investigation of the palæontological evidence can alone, however, remove the question from one of inference to one of fact. [Mr. Hardman maintained the age of the Lough-Neagh beds to be very recent (Geol. Mag. 1879, p. 216), but his arguments appear purely negative. He assumed that Barton's stony wood was pyritized, that Griffiths's section at Sandy Bay transposes the clay and lignites, that the deposition of the clays was posterior to the faulting and denudation of the basalts, that the real *locus* of the silicified wood is the basaltic lignites, &c. He also points to differences between them and the bed at Ballypalady; asks why, if they were there in basaltic times, the basalts did not flow over them; and illustrates his reading by two ideal sections in opposite directions across the lake (Journ. Geol. Soc. Ireland, vol. iv.). If these assumptions and sections were correct, his interpretation would be the right one; but otherwise the lithological difference is not greater than between the interbasaltic formations of Ballypalady, Glenarm, and Mull.] The Lough-Neagh beds seem to have been formed near the southern limits of the basalt-flows, which are vesicular at Shane's Castle; but they are in all probability to some extent overflowed and concealed by trap towards the east.

The nodules containing the plant-remains are usually found on the shores of Sandy Bay only when the level of the Lough is low; though, in company with Mr. Swanston, we obtained an ironstone nodule with leaves in the Boulder-clay from the bank, and two others from the bed of the Glenavy river. The plants these contain are most diversified, though usually small-leaved dicotyledons which at first sight seem of very modern aspect. On closer examination, however, many are found to be characteristic of the English Middle Eocene, and others of the Lower Eocene. Others are common to Ballypalady, to Mull, and to Greenland. This mixture of types, so separated elsewhere, would be difficult of explanation, did the thickness of the deposit not warrant the belief that it may have been continuously forming throughout more than one period of the Eocene. Most of the plant-remains come probably from the higher horizons now exposed on the shores of the Lough; but some of those from the Boulder-clay may come from much lower horizons in it. The flora, however, is by far the most important link yet discovered between the Eocenes of England and those of high northern latitudes, and as such is deserving of most attentive study.

The Ardtun Leaf-bed, Isle of Mull.

This is most accessible on the sides of a small ravine, and it consists there of a much squeezed, indurated, almost black shale, from two to three feet thick, capped with a film of hard grey mud. Both above and below is hard rock, described by the Duke of Argyll as tuff. It seems to extend some 50 yards east, and a less distance west. Several other varieties of sedimentary rock come in and accompany it in its eastward extension, among them a strong mass of current-bedded yellowish-white river-sand. A little above it in the ravine is a mass of angular flints and mud, evidently the result of some sudden volcanic flood. Other beds in the ravine may contain vegetable matter, but I only recognized one that could be termed a "leaf-bed." The top film, for about half an inch, is pale drab indurated mud, and is interesting as marking a change in the conditions, and possibly a volcanic eruption. Less than a foot down is a useful parting of softer matter, which enables considerable blocks of the matrix to be lifted without difficulty. The upper stratum may be described as highly laminated shale, the cleavage-planes being formed by the surfaces of a large-lobed or cordate leaf, while in the lower and less laminated part a small oblong leaf is more sparingly distributed. The whole may have been a fine black fetid silt, such as often results from the overflow of a river when its banks are level. I saw no such regularity as that shown by the Duke in his "pictorial section" of Ardtun.

(For the Discussion, see the end of the following paper.)

13. *The* Tertiary Basaltic Formation *in* Iceland. By J. Starkie Gardner, Esq., F.L.S., F.G.S. (Read December 3, 1884.)

A grant from the Government Fund enabled me to visit Iceland in 1881, with a view of studying its interbasaltic flora. I explored a considerable part of the island and visited every locality that I could reach where lignite had been met with. I did not take notes of some of the localities where my visits were hurried; but the conclusion I invariably arrived at was, that the sedimentary deposits in which vegetable remains are found, are situated among the glassy rhyolitic flows above the columnar series of basalt. The rhyolites are usually pale in colour, and with banded structure, but are sometimes black pitchstone or obsidian. They cap the loftiest mountains of the district west of Akreyri, and extend at least to Baula, a mountain in the same latitude as Snaefell, and possibly beyond this. They also occur on the east coast, though I did not reach any of them in that part of Iceland, which I only visited from the Danish mail-boat, which calls in many of the fiords. I did not pay particular attention to their thickness, but at Sandafell I measured 30 feet of white, pink, ivory-coloured, and black glassy lavas. The thickness is, I believe, sometimes greater than this, and they are interrupted and overlain by smaller flows of basalt. The horizon is, however, certainly continuous, and marks a very definite stage or phase in the great series of Tertiary eruptions which extended from Ireland to Iceland in Eocene times.

I cannot yet present data to show how much younger this part of the Icelandic series may be than the columnar division of the formation in Ireland. Being near the southern limit of the flows, the series may have ceased to be formed at a far earlier period in Ireland than further north; and this I believe to be the case, as there are no fragments of glassy lavas in the Boulder-clays of Ireland. Denudation may, however, have swept very much of the basalt away. There is no base to the formation exposed in either Iceland or the Faröes, and we are therefore ignorant of its total thickness; but some of the mountains reach an altitude of 6000 feet, and are still within its limits. Iceland, like Ireland and Scotland, has also suffered very great denudation. The mountains of the north and east coasts average some 2000 feet in height, and are entirely eroded out of horizontal sheets of basalt. The valleys radiate towards the sea, and many form fiords of considerable size. On the east coast especially, the only remains of the highest layers of basalt are pinnacles or columns along the mountain tops. The mountains are wall-like and continuous, with few lateral openings of no great breadth, and flat-topped in most regions. Their sides are precipitous, except where masked by talus. Glaciation is very conspicuous, and every valley is occupied by a rushing torrent fed by the melting snows of the interior, so that travellers cannot proceed on foot for any distance, except towards the interior. The rarity of dykes is one of the most noticeable features of the basalts; on one occasion I only observed one in a

journey of 30 miles along one of these mountain walls. The oldest basalts are not columnar, and are very compact. The whole series, up to the rhyolites at least, was spread out in vast and almost horizontal sheets, and I saw no indications that any were submarine, except some of the newer beds towards Reykjavik, which occasionally contain sea-shells among the indurated tuffs. They are utterly different in appearance from the recent lava-flows, which always follow the directions of valleys or water-courses, and it seems impossible that they could ever have been erupted from craters, no matter of what magnitude. The recent volcanic eruptions are as utterly independent of the Tertiary system of erupted rocks as an outburst in Ireland, at the present moment, would be independent of the basalts there. They are all Postglacial and fresh-looking, while the Tertiary rocks have been, without exception, eroded on a stupendous scale and subjected to ice-action.

As would be expected, from the fact of their being on such a different horizon, the fossil plants of the Icelandic Tertiaries differ very essentially from those of Ireland and Scotland. The Irish plant-beds are all below the horizon of the columnar basalts, and from their similarity to the flora of the Heersian stage of Gelinden, in Belgium, they cannot be assigned to a later date than the older Eocene. The Mull flora, on the contrary, is situated above some of the columnar basalts, and has already lost the Heersian characteristics, but is still probably of Lower Eocene age. The Icelandic plant-beds are very much newer, and might, from their general character, be assigned to even so late a stage as the Miocene. Some 40 species are recorded, but there are only a few that seem to rest on a sure basis, among them being *Abies*, *Alnus*, and *Acer*. I was not fortunate enough to bring back any extensive collections, but I have had an opportunity of examining, at Copenhagen, those that exist.

Notwithstanding this comparative failure, I do not feel discouraged, but firmly believe that very great results in this direction might attend another visit, especially to the north-west peninsula, to which I have not yet been. Had I been provided with a tent and stores, I might have made longer stays on the spots where plants are likely to occur. Sir Joseph Banks, in his 'Letters on Iceland,' 1780, p. 11, speaks of petrified leaves at Reikum, some of which, in black shale, were brought home. Two localities on the north-west peninsula are mentioned in the 'Flora foss. Arctica,' vol. i. In Olafsen's * exhaustive account there is a precise description of the Surturbrands of Bardestrand, associated with which is a bed of greyish slate divided into laminæ from 3 lines to ½ an inch thick, and containing leaves, among which oak, birch, and willow were easily distinguished. Besides these there were leaves as large as the palm of the hand, which had preserved their minutest venation. The leaves, he says, could with care be removed entire, though as thin as paper. Nine other localities for lignite in this region are mentioned, several of which must be worth investigating.

[I called attention in 'Nature,' August 2, 1883, to two instances

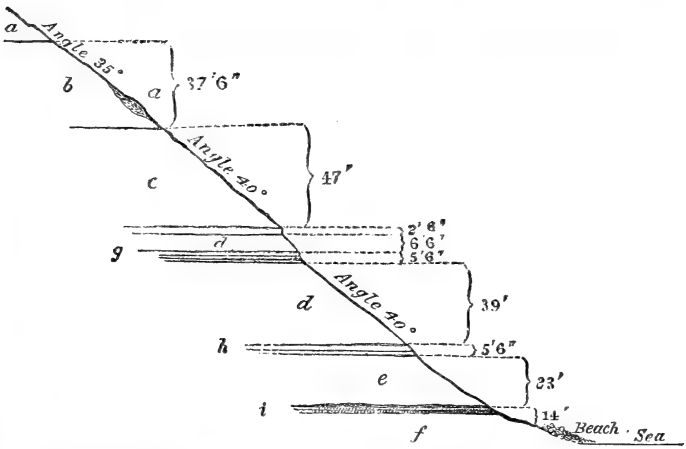
* Vol. ii. p. 393.

where great masses of relatively recent lava debouching from mountain valleys on to plains had produced a very sensible subsidence, leading to the formation of extensive lakes. In the case of Thingválla the plain has sunk at least 100 feet, leaving perpendicular cliffs of lava on the slopes at its northern end, from which the central mass has been torn. These may possibly throw some light on the formation of Lough Neagh.]

Húsavík Marine and Freshwater Beds.

By far the most important of the sedimentary deposits connected with the basalts occurs on the coast 7 miles N.E. of Húsavík, in N. lat. 66° 10′. They rest upon basalt or a basaltic breccia. In approaching them from Húsavík, the first exposure occurs in a grassy *cirque*, named Hringvershujlft, or the "little round valley." The escarpment is about 200 feet high, but slopes at an angle of 45°, and its base is somewhere about 100 feet above the sea-level. The fossiliferous beds rest upon a mass of greenish grey clayey material, succeeded by 20 feet of pale, more or less laminated sandstone with plant-remains. These proved unfortunately to be all of a rush-like nature, much macerated and utterly valueless. Three feet of lignite followed, and then 10 feet more sandstone with similar plants, and then four beds of lignite in succession, each 1 foot thick and

Fig. 1.—*Cliff-section on coast 9 miles N.E. of Húsavík.*

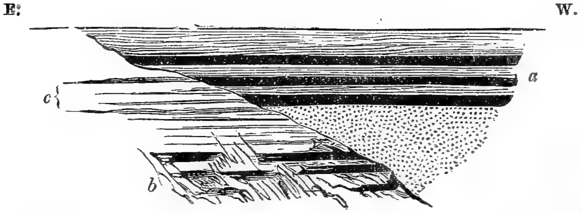


a. Glacial deposits. *b.* Greenish-grey tuff.
c. Sandy clay with broken shells. *d.* Sandy clay, unfossiliferous.
e. Sandy clay with fossils.
f. Sandy clay without fossils, with a band of laminated sandstone with green grains.
g. Four bands with *Cyprina,* the bottom layer with *Actæon Noæ,* and *Cardium echinatum.*
h. Bands of broken shells, with *Cyprina, Actæon,* and *Cardium.*
i. Continuous band of comminuted shells of variable thickness, average 2 feet.

separated from each other, the first from the second by 4 feet and the others by intervals of 3 feet each, of a more compact marl of an almost stony character. The whole is capped by 30 feet of sandstone without plants. About a mile further east the lignites thin and are only four in number and of less uniform thickness. The base is still formed of greenish, indurated, sometimes ferruginous, sandy clay, about 200 feet thick, passing towards the west into a basaltic breccia at its lower part. The lowest bed of lignite is 18 inches thick, and the other three 1 foot each, separated respectively by 16, 12, and 6 feet, and the uppermost surmounted by 14 feet of matrix, terminating with a conglomerate of rounded pebbles. Half a mile beyond this, to the east, the whole of the lignites dip below the sea-level. A mile further along the coast, at the angle of a chine, is the section shown in fig. 1.

The fossiliferous beds rise inland, and cannot be traced more than a few hundred yards up the chine. They are much faulted,—one fault up the chine had a downthrow of 60 feet,—most of the faults being in a N.N.E. direction or nearly parallel with the shore, producing sometimes an apparent overlying of the shell-beds by the lignites (fig. 2).

Fig. 2.—*Fault causing Shell-beds to be apparently overlain by Lignites, near Húsavík, Iceland.*



a. Lignites. *b.* Lignites concealed by débris. *c.* Shell-beds.

Much of the matrix, especially towards the base, is exceedingly like our London clay. The shells occur in bands, and particular species are confined to particular horizons. Across the chine the beds almost immediately dip out of sight (fig 3), and are succeeded by higher and unfossiliferous beds, more compact and indurated, and paler in colour. These are also much faulted.

I ceased to take notes beyond the Cape, but I subsequently rode along the coast to the extreme point of Tjörnes, where I understood lignites had been met with; but for ten miles the unfossiliferous bed seemed to continue without any change.

I endeavoured to determine some of the species by comparison at the Jermyn Street Museum, and submitted the list of names which resulted, and the specimens, to Mr. Searles V. Wood and to Dr. J. Gwyn Jeffreys, who very kindly furnished me with the details embodied in the accompanying table.

Dr. Mörch, in the work referred to above, gives a list of 58

STRIBUTION *and* REMARKS *by* SEARLES V. WOOD, Esq., F.G.S.

narks.	Coralline Crag.	Oldest part of Red Crag.	Middle or main part of ditto.	Newest part of ditto.	Living or not, and where.
....	—	—	×	×	B
....	—	—	×	×	G
....	×	?	×	×	B
....	—	—	—	×	B
....	—	?	×	×	B
....	—	—	—	×	B
....	×	×	×	[illegible]	[illegible]

List of Fossil Shells *collected by* Mr. J. Starkie Gardner *in* Iceland. By J. Gwyn Jeffreys, LL.D., F.R.S.

Table *of* Distribution *and* Remarks *by* Searles V. Wood, Esq., F.G.S.

English Crag.	North American.	European Seas.	Arctic.	Name of Species.	Synonyms and remarks.	Coralline Crag.	Oldest part of Red Crag.	Middle or main part of ditto.	Newest part of ditto.	Living or not, and where.
				Conchifera.						
—	...	—	...	Cardium echinatum, *Linné*						
—	—	...	—	—— islandicum, *L.*		—	—	×	×	B
—	—	...	—	—— groenlandicum, *Chemnitz*						
—	—	—	...	Cyprina islandica, *L.*		—	—	×	×	G
—	—	...	—	Astarte crenata, *Gray*	A. crebricostata, *Forbes*	×	?	×	×	B
—	—	—	—	—— compressa, *Montagu*	Var. striata	—	—	—	×	B
—	—	—	—	Tellina balthica, *L.*		—	?	×	×	B
—	—	...	—	—— calcaria, *Ch.*	And var. obliqua	—	—	—	×	B
—	...	—	—	Mactra solida, *L.*		×	×	×	×	E
—	—	...	...	Mesodesma deauratum, *Turton*		—	—	×	×	B
—	—	...	—	Glycimeris siliqua, *Spengler*	? G. angusta, *Nyst*, fide *Searles Wood*	—	—	×	×	A
—	—	—	—	Mya arenaria, *L.*		×	—	×	—	E
—	—	—	—	Saxicava norvegica, *Sp.*		...	×	×	×	B
				Gastropoda.						
—	—	—	—	Littorina littorea, *L.*						
—	—	...	...	Natica heros, *Say*	N. catenoïdes, *Searles Wood*	—	—	×	×	B
—	—	...	—	—— affinis, *Gmelin*	Var. occlusa.	—	×	×	—	E
	—	...	—	—— aperta, *Lovén*	Bulbus flavus, *Gould.*					
—	—	...	—	Buccinum groenlandicum, *Ch.*		—	×	—	—	G
	—	...	...	Murex cinereus, *Say.*						
	—	...	—	Fusus despectus, *L.*						
	—	...	...	—— curtus, *Jeffreys*	F. Stimpsoni, *Morch*; F. Olavii, *Beck*	...	?	?		
	—	...	...	Nassa trivittata, *Say*	? N. propinqua, *Sby.*; *Searles Wood*	—	×	×	—	A?
—	...	...	...	—— monensis, *Forbes*		—	—	×	—	E
—	—	—	—	Pleurotoma turricula. *Montagu*	Var. Fusus harpularius, *Couthouy*	—	×	×	×	B
	—	...	—	—— pyramidalis, *Ström*	F. pleurotomarius, *Couth.*	—	—	×	×	A
—	—	...	—	—— bicarinata, *Couth.*		—	—	×	—	A
—	...	? —	...	Actæon noæ, *J. Sowerby*	? Tornatella pusilla, *Forb.*	—	×	×	—	E
20	23	10	18	27						

Notes on Dr. J. Gwyn Jeffreys's List.

The term "Arctic" in the fourth column of this list includes not only those parts of the Atlantic and Pacific Oceans which belong to America and Asia, but also those parts of the European seas which lie within the Arctic circle.

The list shows that of the 27 species collected by Mr. Gardner, 20 are found in the English Crags, 23 live in the North-American seas, 10 only in the European seas as above restricted, and 18 in the Arctic seas of both hemispheres. It also shows that nearly the same number of species occur in the Crag and North-American seas; 16 species are common to both those categories; 5 appear to be American, and 3 Arctic, none of which are Crag. The connexion between the Crag and North-American Mollusca is therefore more intimate than between the Crag and European Mollusca, not taking the Arctic Mollusca into account. Two species, and those questionably, are supposed to be extinct. I should regard this Iceland deposit rather as Post-tertiary or Quaternary than as Pliocene.

All the non-existing species are inhabitants of comparatively shallow water; some are littoral.

The peculiarly North-American species (*Mesodesma deauratum*, *Natica heros*, *Murex cinereus*, *Fusus curtus*, and *Nassa trivittata*) have not been recorded as living on the Icelandic coasts. Iceland is geographically separated from North America by Greenland, where the marine Mollusca are more European than American*. But the course of the Great Arctic current is from Iceland to Newfoundland and the western coasts of North America; and this may account for the former occurrence of North-American species in Iceland, as evidence of their origin or source of distribution at that epoch when the shells were overwhelmed by a volcanic flow of lava. All the Mollusca which now live in the Icelandic sea are either Arctic or North European, and have apparently been derived from Spitzbergen or Finmark by means of the same current which is continued from Iceland to Newfoundland.

J. Gwyn Jeffreys.

4th Dec., 1884.

* See my paper on the 'Valorous' Expedition in the 'Proceedings' of the Royal Society for 1875.

Notes on Mr. S. V. Wood's Table.

B. Signifies living in British seas and elsewhere.
A. On North-American coast only.
G. Greenland and Arctic seas only.
E. Not known as living.

The large carinated shell referred to (p. 96) is probably *Trophon antiquus*, var. *carinatus*. Mr. S. V. Wood remarks that only the sinistral form of *T. antiquus* occurs in the oldest part of the Red Crag, and this not carinated. Both the sinistral and dextral forms of var. *carinatus* occur in the middle part of the Red Crag. It is the carinated form which is Arctic, not British.

To these we may add the following species, overlooked by Dr. Gwyn Jeffreys, identified by Mr. Searles V. Wood, and also occurring in the paper by Dr. Mörch on the Iceland Crag at p. 321 of vol. viii. of the Geol. Mag. (1871):—

Buccinum Dalei, only a fragment or two of which are known from the Coralline Crag, though it is very abundant in the older and middle part of the Red Crag.

Pleurotoma hispidula, a rather doubtful Coralline-Crag species, now living in the Mediterranean.

Mactra arcuata, known throughout the Crags and extinct.

Tellina obliqua, rare in coralline and older parts of the Red Crag, but abundant in the rest of the Red Crag and in the oldest Glacial beds. Treated as a variety by Dr. Gwyn Jeffreys.

T. prætenuis. Very abundant in both middle and newest part of Red Crag, but rare in the oldest Glacial beds. In the newest part of the Red Crag both these Tellens are associated with the living Arctic species, *T. calcaria*, which occurs in all Glacial beds. Both *T. obliqua* and *T. prætenuis* are unknown from any but the oldest Glacial beds, and of the east of England only. They are now extinct.

There are also a few species remaining undetermined. Mr. S. V. Wood, from the evidence before him, regarded the bed as not later than the Middle Red Crag, and he remarked on the close affinity between their Mollusca.

species, at least 16 of which are of very doubtful value. I was unable to extract a large fusiform shell, which was much cracked, and in an almost inaccessible position; but I made a drawing with measurements, before attempting to remove it, and saved the greater part of it. This can be reproduced when necessary.

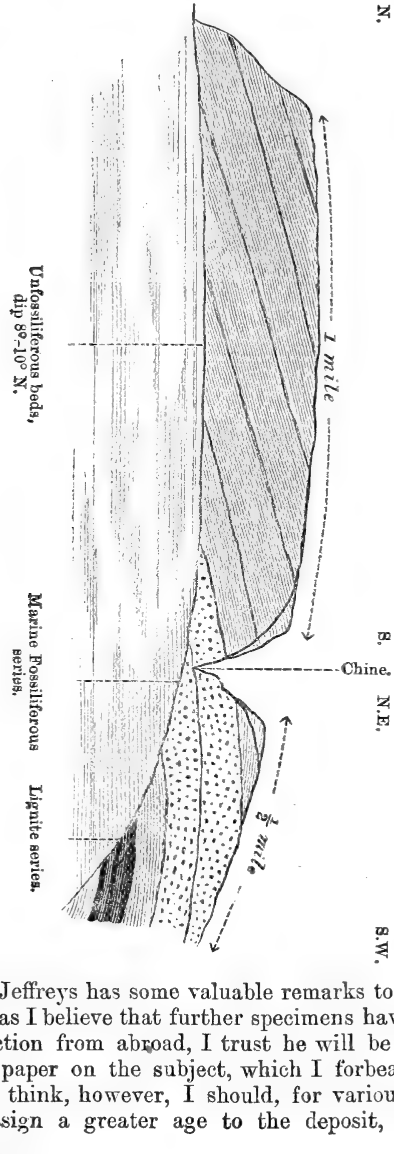


Fig. 3.—Cliff-section showing the Position of the Marine series of Húsavík, Iceland.

Dr. Gwyn Jeffreys has some valuable remarks to make upon these fossils; but as I believe that further specimens have been submitted to his inspection from abroad, I trust he will be induced to communicate a paper on the subject, which I forbear in any way to forestall. I think, however, I should, for various reasons, be inclined to assign a greater age to the deposit, from its general

appearance on the spot, than Dr. Gwyn Jeffreys may do, or even than Mr. Searles Wood. The occurrence of the fauna of the Red Crag, with Mediterranean species, so many degrees north, would dispose me to consider them as belonging to a somewhat warmer climate and therefore presumably to a rather earlier period than I should do if meeting with the same assemblage further south.

This part of the country is a table-land, with mountains some distance inland, from which lava streams have issued in relatively recent times. Nearer Húsavík the cliffs are of basalt and volcanic breccias, and to the east the plateau is composed of horizontal basalts with a thick alluvial capping of loam, ready to produce a bed of laterite if ever again overflowed by lava streams.

It is impossible, from the coast-section, to form any just idea of the relationship of this sedimentary formation to the Tertiary basalts; and the determination of its precise age cannot, unfortunately, at present throw any light upon their history, though presenting a problem of great independent interest.

Coal is said to occur near the base of the mountains on the opposite side of the bay, facing Húsavík; and as these do not present a basaltic contour, they might be worth investigation.

Tjarnir ("short lakes").

About 25 miles due south of Akreyri is a valley the sides of which, about 2000 feet high, are composed of basalt, scarcely intersected by any dykes. The coal reported to be found here proved to be obsidian. The rhyolitic lavas overlying the basalts form a very important series at this point.

Sandafell (not the Sandfell marked on maps).

This mountain is situated about 25 miles S. of the Skagafjörd, and 6 miles above Abaer, the nearest farmhouse, on the river Banda. The basalt is covered by a clay bed with rootlets a foot thick, succeeded by brown coal passing into lignite, another foot, and then 150 feet of volcanic breccia, with large blocks of basalt imbedded towards the base. There are then 30 feet of pale tuffs, and a band of pitchstone decomposed into vertical needles overlain by pink and ivory-coloured banded rhyolites, and finally basalt. This section is at the angle of the two valleys formed by the rivers Tinnaa and Banda; and, looking up the former, the pitchstone band is conspicuous between the lighter masses for at least a mile, being on the right hand at an elevation of about 600 feet, and at least 800 or 900 on the left. Up the Banda the lignite thickens to 3 feet.

Well-preserved leaves have been obtained from the yellow tuff, and are now in the University Museum at Copenhagen. Though I searched diligently, I was not fortunate enough to discover any bed with fossils worth bringing away. At the corner of the Tinnaa are magnificent groups of columnar basalts, bent in many directions, and twice fanning out like the clam-shell cave at Staffa. Some fallen segments measured 3 and 4 feet in diameter. The pale-

coloured rhyolites reappear in all the mountains at a high level as far as Akreyri.

Hof.

A few miles south of Godalir, at the angle formed by the first tributary to that river on its left bank, the section has been cut through by the stream, and forms a perpendicular bank 12 feet high, in which are over twenty layers of lignite separated by gritty marls and ferruginous bands, crowded with vegetable matter, with a soft sandstone at base, similar in appearance to that of Húsavík. At 12 feet a bed of lignite composed of compressed tree-trunks occurs, and then another, 3 feet thick. The bank then slopes at an angle of 30° for a distance of 60 feet, still abounding in lignitic matter, when it is concealed by the greatly overhanging remnant of an old moraine. On the opposite, or south bank, the same beds are capped by columnar basalt. The plants again proved to be nothing but rush-like monocotyledonous débris, with seeds, and probably remains of *Chara*. The dip shown in both exposures (S.E. and N.) is 9°, and the formation is probably extensive. The diameter of the largest compressed trunk I extracted was 20 inches; but this did not seem to be the full width. There were many large trunks in the bed of the stream, the branching of which suggested willows of large dimensions.

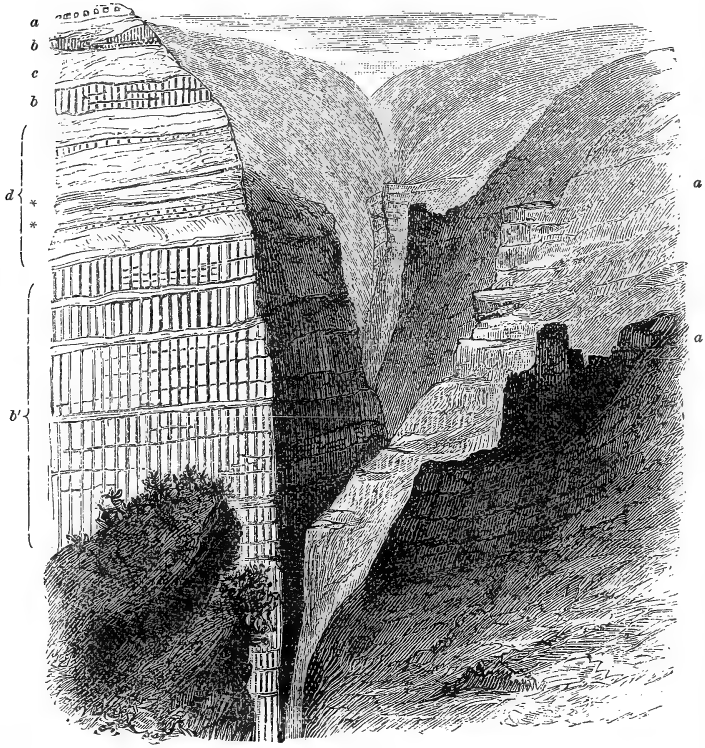
In this neighbourhood, about 7 miles from Hofsgil, a magnificent section of over 1000 feet in depth can be studied (fig. 4). It forms the side of one of the wildest conceivable gorges or cañons. The precipitous and even perpendicular sides are composed of more or less columnar basalts, separated by partings of almost vermilion-red earth, which has stained them a reddish purple. Where the sides are not perpendicular, fragments of the old moraines, cold slaty grey in colour, cling to them, weathered into fantastic shapes and looking like ruined masonry. The torrent is just visible as pure white foam at the bottom. The section here reproduced is of general interest as showing the composition of the ordinary North Icelandic mountain from top to bottom. Its upper part, as viewed from across the gorge, forms a slope of from 50° to 60°, and overhangs a tremendous precipice, so that it would not be accessible without great danger. It is evidently similar to Sandafell, not many miles distant; and that the black band is really lignite is apparent from my subsequently picking up pieces in the bed of the river.

This gorge was evidently at one time filled in solid with Boulder-clay or moraine, and enormous masses of rolled stones are spread over the valley below. The stones have been arranged into sharply defined terraces. A river entering from a valley to the east had accumulated an enormous mass of shingle, before the main river cut its way through and cut down at least half the area to a level of 30 or 40 feet lower; after which the rivers united and further reduced it as much again, affording an instructive example of terrace-formation.

A better clue to the formation of parallel roads is furnished by a

small valley, marked Sandklettavátn, about lat. 64° 21′, between Reykholt and Thingválla. It is marked as a lake without any outlet; but in August there was only a little water at one end, the stream

Fig. 4.—*Cliff and Ravine about 7 miles from Hofsgil, height about 1000 feet.*



a. Boulder-clay. *a′.* Boulder-clay weathered into architectural forms.
b. Basalt. *b′.* Basalt with partings of bright red and brown earth.
c. Rhyolite. *d.* Sedimentary rocks, about 130 feet, chiefly yellow and drab sandstones, with two intercalated bands of lignite, marked **.

connecting it with Ukavátn being also dry. The plain is level, destitute of vegetation, about three miles long and one broad, closed in on three sides by mountains and on the fourth by a lava-stream. Its shores are regularly terraced all round, the terraces being only 2 or 3 feet high. It is evidently a shallow lake for a great part of the year, and the terraces have some connexion with the recurring formation and disappearance of a dam of snow or ice at its eastern extremity.

Hredevátn.

This is a small lake in western Iceland, lat. 64° 41′. A bed of coal occurs in a romantic ravine about 800 feet above the lake, and towards its northern end. The coal is but 18 inches thick, and is immediately under a bed of basalt, with yellow tuffs underneath it. It reappears in a gully 100 yards to the N. W., with a dip of about 15° to the S. W. The section is entirely overgrown and covered by earth, and would require much time to uncover; but I exposed a bed of brown papyraceous shale, and underneath it a short brittle sandy clay, with rootlets and vegetable remains. Above the shale there was yellow tuff; but several hours' search brought forth nothing in the shape of well-preserved leaves, though they are stated to have been found in the tuff at this spot. Another lignite or coal bed is said to occur four hours' ride to the west.

The coal is used for fuel, but is as costly to obtain, owing to its inaccessible position, as sea-borne Scotch coal.

Stafholt.

This locality is a small promontory six or seven miles south of Hredevátn, on the banks of the river, and nearly at the sea-level. The point forms a low cliff, and does not extend beyond 50 yards. The matrix is a coarse yellow brecciated tuff, in which trees of considerable length and girth are imbedded separately, and principally on one horizon, only a few feet above the water. Smaller pieces of wood lie above. These trunks are partly in the condition of lignite, and partly imperfectly silicified, with their structure beautifully preserved. The deposit is much cut up by dykes.

Discussion.

Dr. Gwyn Jeffreys said his attention was called to the Icelandic beds with fossil shells by Prof. Steenstrup at Copenhagen in 1869, and further material had been collected by the late Dr. Mörch, to whose memory as a conchologist the speaker offered his tribute of admiration. It was remarkable that among the shells there were very few Arctic species. It reminded him of the Moel-Tryfaen assemblage of shells, among which temperate forms occurred in great abundance.

Prof. Judd stated that the series of rhyolites brought from the north of Iceland by the author consisted of stony rhyolites, exhibiting banded spherulitic and perlitic structure, passing into pitchstone and obsidian. Some of the rocks are vesicular and even pumiceous, and they are associated with obsidian- and pumice-tuffs.

Mr. Etheridge bore testimony to the great perseverance shown by the author in working out the Icelandic and Irish beds. He thought the collection of shells from Húsavík was of the most interesting character.

The Author said that many of the shells occur in beds of about a foot thick. The shelly beds are covered by great thicknesses of stratified but unfossiliferous ashes.

14. *The* Drift-deposits *of* Colwyn Bay. By T. Mellard Reade, Esq., C.E., F.G.S. (Read January 14, 1885.)

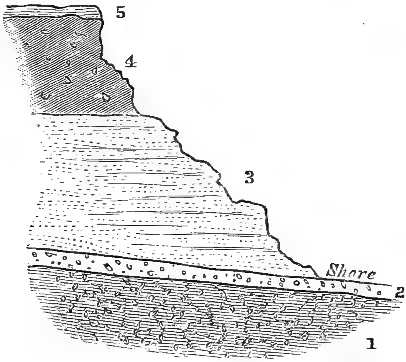
In a former paper* I gave a short sketch of the drift disclosed in the ballast-pit at Colwyn-Bay station; and as in February of 1884 I had an opportunity of extending my observations over a larger area, I now propose to give an account of them.

From Colwyn Head to Rhos Point is a distance of about three miles; and all along the shore, except where obscured by the Colwyn-Bay parade or grassed over by the railway company, are to be seen in cliffs excellent sections of the drift.

This drift, extending backward to the foot of the hills which sweep in a curve from headland to headland, rests nearly wholly on the Silurian rocks, representatives of the Wenlock Shale.

Colwyn Head or Penmaen Cliffs, and Rhos Point, are denuded remnants of the Carboniferous Limestone, and near to each of these headlands the drift is seen to rest directly on the limestone, there being no exposure of the underlying Silurians anywhere to be seen in Colwyn Bay.

Fig. 1.—*Section just beyond the Cottage west of the Colwyn-Bay Hotel.*



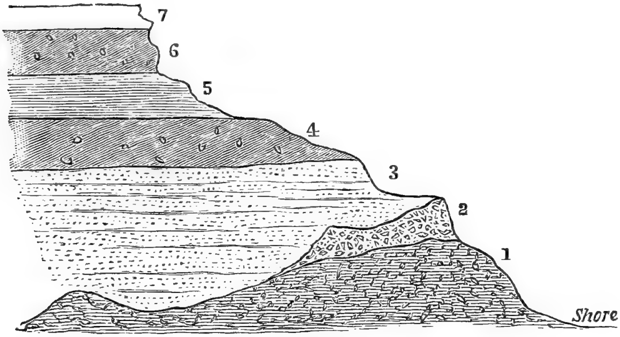
1. Grey Till, packed full of stones, partly Silurian Slate and Grits, and Carboniferous Limestone.
2. Cream-coloured Till. 3. Sand. 4. Brown Boulder-clay. 5. Soil.

The surface of the drift is remarkably level, excepting where it gradually creeps up the hills. Most of the houses in Colwyn Bay are built upon it. It is crescent-shaped on plan, thinning out to-

* Drift of N.W. of England and N. Wales, part ii. Quart. Journ. Geol. Soc. vol. xxxix. p. 111.

wards the outward curve, which rests on the hills, and thickening towards the Bay.

Fig. 2.—*Section West of fig.* 1.



1. Bluish-grey Till; and, 2. Cream-coloured Till, as in fig. 1.
3. Sand. 4. Brown Boulder-clay.
5. Finely laminated Boulder-clay. 6. Brown Boulder-clay. 7. Soil.

The drift may be roughly grouped into three divisions in ascending order, as follows:—

1. *Bluish-grey Till* (bed 1, figs. 1 & 2), hard and tough, evidently composed of the combined grindings or decomposed particles of the Silurian and limestone rocks, and full of striated slaty rocks, limestone, Carboniferous grits, conglomerates, and trappean and ash rocks common to North Wales.

This Till is not visible between the Colwyn-Bay station and the road under the railway from Old Colwyn, but between the latter place and Colwyn Head may be seen a mixed grey and brown Till. It may be seen on the foreshore opposite the Colwyn-Bay Hotel, and from thence appears at various points, rising up in bosses in the cliff sections until we reach Rhos village. It may also be seen on the foreshore opposite the cottage west of the hotel (fig. 1). From Rhos point westward, to the embankment across the marsh, it may be traced. At one point here, I observed a very large limestone block imbedded in it. The Till continues from the west end of the embankment to the Little Orme's Head.

The surface of the Till, which everywhere, excepting on the foreshore, is overlain by the Brown Boulder-clay, presently to be described, possesses an uneven denuded surface, and is in places covered with a cream-coloured deposit packed with stones, apparently the wash of the Till below, one or two feet thick, as the case may be (2, figs. 1 & 2).

I looked for granite boulders in this Till; but though they were not unfrequent on the foreshore, I could not find any actually imbedded, but I had no opportunity of making an exhaustive

examination. It may, at all events, be averred that they are not common in it *.

At the cottage before mentioned, between Colwyn-Bay hotel and Rhos, I noticed a large granite boulder on the shore, full of large crystals of felspar, which looked uncommonly like grey Shap granite. The crystals of felspar did not, however, form protuberant knobs, as is often the case with boulders of Shap granite. It is probable that it may be either Shap or Cairnsmore of Fleet granite †.

On the foreshore opposite the Colwyn-Bay hotel, the character of the stones contained in the Till may be readily studied. They are mostly slaty rocks, flattish in form, and often rounded at the edges. The Till being of a very tenacious nature, the stones remain firmly fixed in it, though their upper surfaces and sides are exposed by the denudation of the waves. The striations are distinctly to be seen on most of the stones, though doubtless partly effaced by the attrition of other boulders and shingle moved by the sea.

It is really remarkable how they retain their ice-markings under the circumstances. I looked for signs of striated pavements, but could not find any; the boulders are fixed in the clay at different angles, and the stones do not show striations in a parallel and uniform direction.

2. *Low-level Boulder-clay and Sands* (beds 3 & 4, fig. 1; & 3, 4, 5, & 6, fig. 2).—The Chester and Holyhead Railway runs along the top of the drift near to the edge of the cliff, so that in places the railway company have made what formerly was cliff into railway-bank, by sloping and grassing it over. For this reason it is difficult to see what the bank is composed of near Colwyn-Bay station, but it appears to me to be a continuation of the gravel, shingle, sand, and clay beds seen in the ballast-pit.

If this be so, it gradually changes into the Low-level Boulder-clay and sands which overlie the Blue Till over the whole of the area described in this paper.

This Low-level Boulder-clay and sands is evidently a marine deposit, and contains shell fragments. There are very few boulders in it; but in places a great many beds of shingle and gravel, which are, however, best displayed in the inland excavations, and at the sides of the brooks which run from the hills through the drift and across the railway to the bay.

The clay is brown and decidedly sandy, and the sand-beds, often displaying current bedding, are well developed, and form an important feature in the drift. I believe most of the erratics on the shore come from this bed. Among the loose shingle on the shore are to be observed many Eskdale and grey Scotch granites, which no doubt have originally been derived from this group of beds.

Inland Sections.—Inland on the north side of the road, behind the Hydropathic Establishment, is a large brick-pit in this clay, and

* Mr. Mackintosh says he "dug out of the blue clay two pebbles of Eskdale granite." "Age of Floating Ice in North Wales," see Geol. Mag. 1872, p. 16.

† See "Notes on Rock-fragments from the South of Scotland," Quart. Journ. Geol. Soc. vol. xl. pp. 270–272.

there are also others near the Board Schools on the road to Llandrillo-yn-rhos. Nearer Colwyn-Bay Wesleyan Chapel, on the same road, is a sand-pit. I believe the beds of clay and sand are discontinuous, and occupy the surface without any particular order.

3. *Rearranged Gravels.*—A good deal of the drift surface, especially about Colwyn-Bay village and in the neighbourhood of the several brooks before mentioned, shows evidence of having been subaerially redistributed. It is difficult to draw a fine line between these gravels and those undoubtedly belonging to the drift, especially as the surface-deposits had doubtless been previously rearranged or deposited during the emergence of the land from the great submersion. At the new station at Old Colwyn, which was being built during my examinations, the excavations showed a shaly gravel occupying the surface.

Alluvium.—A deposit of marsh clay is to be seen on either side of the embankment between Rhos and the Little Orme's Head. It is only a few feet thick, and rests upon a few inches of peat, which again rests on the "brown Boulder-clay." The surface of the Low-level Boulder-clay is at its minimum elevation at these points. I was unable to measure the heights of the cliffs, but I should judge that the railway was at an average level of about 40 feet above the shore of Colwyn Bay. Towards Rhos the surface-level of the drift declines to near the shore-level. Beyond the embankment towards the Little Orme's Head it rises again to a considerable height.

Denudation.—The sea has evidently cut into and washed away a great deal of the drift, hence the formation of the cliffs. The "Dingle" at Colwyn Bay, and the valley or gully in which runs the brook from Old Colwyn, are very deep narrow cuts in the drift. I attribute their depth and comparative narrowness to the geological recency of the denudation of the coast, which has brought the "base level of erosion" nearer to the hills, and so, by quickening the grade of the streams, has enabled them to do more work vertically than horizontally.

Conclusion.

It now remains to consider what light the foregoing facts throw upon the difficult question of Glacial geology.

In the first place I may observe that in few sections is to be seen so clear a line of demarcation between two beds of drift as exists here between the grey Till and the brown Boulder-clay. This arises from the fact that the clearly marine "Low-level Boulder-clay," and the typical "Till" are in juxtaposition over a comparatively large area. "Till" is evidently a deposit the materials of which generally have not travelled so far as those of the Low-level Boulder-clay. It is here, as elsewhere, largely, if not altogether, made up from the local rocks, the slates, shales, and limestones, and it is no doubt the great quantity of carbonate of lime in it that makes it set so hard. At Penmaenmawr, to the west of Colwyn Bay, and out of the limestone district, I had an

opportunity of examining in the foundations of the British Schools, of which I happened to be the architect, the Till lying on the hill-side. Here and all about Penmaenmawr, after getting below the surface-affected portion, it was a hard grey Till full of large boulders and stones which were generally more or less rounded and waterworn. I noticed one slightly striated. These stones were so large and firmly imbedded that they were used in some cases for the foundations, being built into the walls without removal. The Till at Colwyn Bay is bluer, more clayey, and of a finer texture, and contains not nearly so many large boulders, though the total bulk of the stones in it may not be very dissimilar. According to my experience, true Till is rarely, if ever, found except in the neighbourhood of mountains or quickly sloping ground. In the present instance, I am inclined to believe that it has been formed by ice and snow descending from the mountains and accumulating the disintegrated matter at the foot. It does not appear to be the ground-moraine of a hill-and-valley-ignoring ice-sheet, as the contained stones lack the definiteness of direction one would expect to result from such an agency. It is better to admit that we are largely ignorant of the various modes in which land-ice acts—its effects, with our limited knowledge, belonging more to speculation and theory than to fact.

Be this as it may, when we come to the overlying deposit of brown Boulder-clay, no such difficulties occur. It is undoubtedly an aqueous-marine deposit, and part of the extensive sheet of Low-level Boulder-clay and sands which occupies all the plains of the North of England, from the margin of the mountains to the coasts of the Irish Sea, and, skirting the coast of Wales, here and there intrudes upon the lower valleys. With the exception of the portion of this deposit which approaches the limestone headlands, where it is mixed with the detritus therefrom, the extensive sheet of drift, which I have described as lying in Colwyn Bay, is composed to a large extent of travelled materials. The sands and clays of which it is composed are not what the immediate coast or mountains could yield. It is, in fact, a deposit almost identical with the sandier of the Boulder-clays near Liverpool, which are composed principally of Triassic débris, mixed with travelled and striated rocks. I have previously stated "The sands and clays of Colwyn are evidently derived from the Triassic rocks of the Vale of Clwyd" *. This further and more careful examination over a large area has confirmed me in this opinion. Four and a half miles east of Old Colwyn, the Triassic sandstones set in and extend eastwards a distance of nine miles across the mouth of the Vale of Clwyd. Most probably these rocks also extend seawards. The materials of which the bulk of the Colwyn drift is composed, has in the first place probably been worn off the Triassic sandstone by subaerial agencies, including under that head ice and frost, and has worked gradually down the valley, it may be, to the plains now occupied by the Irish Sea. On

* Quart. Journ. Geol. Soc. vol. xxxix. p. 118.

the gradual submergence of the land, this material lying in the Vale of Clwyd, reinforced by other material continually being worn off the rocks, and working seawards, has washed round the coast towards the Little Orme's Head, and become mixed with other material washed up from the sea-bed and with argillaceous matter from the underlying Till. No ice-sheet will account for this drift. It is evidently a marine drift. The Eskdale-granite boulders which it contains must have travelled to where they lie by floating ice; for many of the boulders have come from the north, while the sands have been derived from the east. At all events, if this be not a true explanation, all the complicated machinery of at least two ice-sheets will have to be invoked. This appears to me to be unnecessary, especially as it would not explain the structure of the drift, which bears internal evidence of aqueous deposition.

Discussion.

Mr. W. W. Smyth remarked on the interest of this paper, as these beds of Colwyn Bay are evidently connected with the drift-deposits of the Vale of Clwyd, proved to be of great thickness in coal-borings at Rhyl. On the other hand, the classic deposits of Moel Tryfaen might also be connected with the same deposits.

Dr. Hinde pointed out that Till, undistinguishable from that in Wales, covers extensive areas in North America, far away from any mountains, and that consequently these are not essential to its formation.

Mr. Whitaker bore witness to the great care with which Mr. Reade worked out his results by tracing the region from which the different stones came. He himself hardly understood the difference between Till and Boulder-clay.

Dr. Hicks said that in the Vale of Clwyd we have three stages:—local deposits of gravel, marine sands, and widespread Boulder-clay. He thought that the Boulder-clay was formed by a mixture of local materials and ice-borne blocks.

Mr. Topley pointed out that the main interest attaching to the paper arose from the care with which the section had been recorded and the origin of the different materials traced. The succession of beds described was that generally to be seen in the North of England, where the drift-deposits are well developed. In Northumberland and Durham the middle sands usually occur in greatest force near the old preglacial valleys.

Prof. Judd, in the absence of the author, further explained his views as to the distinction, character, and relations of the Till and Boulder-clay of the district.

15. NOTES *on* SPECIES *of* PHYLLOPORA *and* THAMNISCUS *from the* LOWER SILURIAN ROCKS *near* WELSHPOOL, WALES. By GEORGE ROBERT VINE, Esq. Communicated by Prof. P. Martin Duncan, F.R.S., F.G.S. (Read December 17, 1884.)

MR. G. W. Shrubsole, in a paper "On the Occurrence of a new Species of *Phyllopora* in the Permian Limestone"*, remarks that "the genus *Phyllopora* has as yet been but imperfectly worked; its rarity in the more recent and its imperfect preservation in the older rocks go far to account for this. . . . . In the Lower Silurian rocks *Phyllopora* is most abundant. There are at least two distinct species, if not more. The preservation of the remains in these beds is most unfavourable for exact work, occurring, as they often do, in coarse ash or shale, and distorted by cleavage."

In the collection of the School of Mines there were † several specimens of *Phyllopora* catalogued and labelled as such, which I was allowed to examine when collecting material for my Second British Association Report on Fossil Polyzoa. The specimens from the Lower Llandeilo rocks are the common forms, generally designated *Retepora* by early authors. One specimen is in the Wyatt-Edgell collection, and we have only the reverse aspect of the form; but in places where the branches are worn the cells can be seen, not sufficiently, however, to enable us to make out their character. The fenestræ are oval or irregular, branches anastomosing, consequently without dissepiments.

In the Caradoc series of fossils of the same collection, several specimens are labelled, and also catalogued, as *Phyllopora Hisingeri*, M'Coy, and one, belonging to the Wyatt-Edgell collection, is catalogued as *P. ornata*, MS. Generally speaking, all these forms are very indistinct or ill-preserved. In a box with one specimen ($\frac{4}{70}$ Case V) labelled *Phyllopora*? *Hisingeri*, M'Coy, a small portion of the zoarium of *Retepora cellulosa*, Linné, is placed for the purpose of comparison. The Lower Silurian fossil is from Robeston Wathen, Pembrokeshire. I have several specimens of *P. Hisingeri*, M'Coy, in my cabinet; for it is the most common of all the forms found in the Caradoc or Bala beds; but it is only by careful manipulation, and adjustment of light, that the cell-structures of these species can be made out; and even then not much dependence can be placed on the diagnosis. In the Lower Llandovery beds one specimen is marked and catalogued (*op. cit.* p. 64) as *Phyllopora*, sp. Besides these I have no other knowledge of species of the genus found in the Lower Silurian rocks in Britain sufficiently characteristic to be individualized.

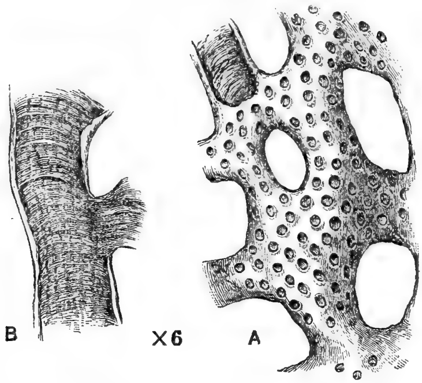
In the beginning of August, 1884, Mr. J. B. Morgan, of Welshpool,

* Quart. Journ. Geol. Soc. vol. xxxviii. pp. 347, 348.

† In 1881. See Catalogue of Mus. Pract. Geol., Cambrian and Silurian fossils, 1878.

sent some fossils to Professor Lapworth for identification. Amongst them were some Polyzoa. These Professor Lapworth asked Mr. Morgan to send to me, and their study has enabled me to throw a little light on essentially characteristic features of at least one Lower Silurian species of *Phyllopora*. This is clearly not the *P. Hisingeri* of authors, and I shall be compelled, much against my wish, to characterize it as new.

Fig. 1.—*Portions of* Phyllopora tumida, *sp. n.*
(Enlarged 6 diameters.)



A. Poriferous surface.
B. Interior of non-celluliferous face.

1. Phyllopora tumida, sp. n. Fig. 1.

Zoarium an open net-work of undulating branches; base and general dimensions of zoarium unknown, branches anastomosing, apparently thick, occasionally tumid, and varying in breadth from one tenth to one twelfth of an inch. *Fenestrules* oval or irregular, sometimes less, but occasionally rather longer than the breadth of the branches. *Zoœcia* tubular, short or stunted, cell-mouths circular, prominent, with a rather thick peristome, from four to five arranged diagonally in the branch. Reverse, on account of the peculiarity of its preservation, indistinct.

Horizon and Locality. Caradoc beds; Wern-y-seadog, Llanfyllin.

Cabinet. J. B. Morgan, Esq., Welshpool; 2 specimens.

I have been fairly successful in drawing a portion of two branches, on which the cell-characters are pretty distinct. The specimen from which the drawing is made is rather more than half an inch square; it contains about twenty-three perfect and imperfect fenestrules, and nearly the whole of the branches are more or less covered with cell-apertures (fig. 1, a). In places where the cells are worn the tubular prolongations are seen, and, judging from the peculiarities of the form, I should not imagine that the branches are

thick. In places where the whole of the cells are worn off, their former localization is indicated by wavy outlines, as shown in fig. 1, B; but I cannot trace any other special character of the reverse than this. With the exception of the prominent lips of the cells of the species, nearly the whole of the original organic matter of both specimens is replaced by iron oxide; consequently the once living form now appears upon the shale as a dark brown friable mass. Because of this, I am unable to fill in all the details that are necessary for the full study of Lower Silurian species. It is to be hoped, however, that the publication of these brief notes may be the means of bringing to the front other fossils with the poriferous face exposed, rare though they may be.

Prof. H. A. Nicholson has described one species of *Phyllopora* from the Trenton Limestone, Peterborough, Ontario *, and as the Trenton Limestone is of, or about, the same age as our Caradoc beds, the species is interesting for the sake of comparison. The Ontario form is named *Retepora trentonensis*, Nich., and the fossil was only known to the author "by several more or less imperfect specimens, from which some of the essential characters cannot be determined." There is no possibility of uniting the two forms under one specific name, because, even from the characters which Prof. Nicholson was able to draw up from the best of his specimens, there are many differences between them, as a comparison of the two descriptions will show. The Ontario specimens are better preserved than ours, and we learn from the description that the "reverse aspect is strongly striated with wavy or straight longitudinal striæ." In the Caradoc species I cannot trace any other character of the reverse aspect than that already given.

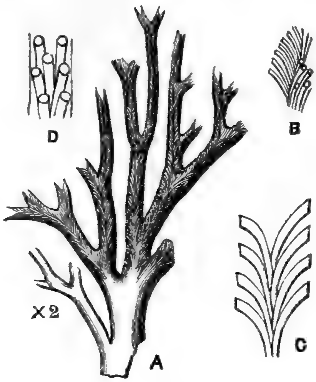
Mr. E. O. Ulrich describes † and figures one species of *Phyllopora* in his series of papers on "American Palæozoic Bryozoa." This he names *P. variolata*, Ulr., but he says "the genus is represented by two species in the Cincinnati rocks, *P. variolata* and another which I believe is the same form that was described by Miller and Dyer‡ under the name of *Intricaria clathrata*." The species found in our British rocks is related to, but not identical with, Mr. Ulrich's. In his species the "cell-apertures are arranged either in two series or three alternating rows; intercellular spaces thin, raised into small nodes where longer; about fourteen cell-apertures occupy the space of ·1 inch. Branches on non-celluliferous side smooth."

Locality. Cincinnati, Ohio, in strata from 150 to 325 feet above low-water mark, in the Ohio river.

There is another fossil in Mr. Morgan's collection that merits distinction and description, not more on account of its peculiarly antique character than on account of its mode of preservation in the volcanic ash in which it is imbedded.

* New Palæozoic Polyzoa, Geol. Mag. Dec. 2, vol. ii. p. 2, f. 4, 4 *b*.
† Journal Cincin. Soc. Nat. Hist. Oct. 1882, p. 160, pl. vi. f. 14.
‡ Contributions to Palæontology, no. 2, 1878.

Fig. 2.—Thamniscus antiquus, *sp. n.*



A. The specimen, enlarged 2 diameters,
B, C, D. Details more highly magnified.

2. Thamniscus antiquus, sp. n. Fig. 2.

Zoarium apparently springing from a root-like base, strong and thick towards the bottom, where several root-branches appear to be united, more delicate towards the younger or growing portion of the zoarium. Branches frequently dichotomising, free. *Zoœcia* tubular, shown on one side only of the branch. Tubular cells not contiguous, rather broad at the openings, gradually thinning out towards the axial region of the *zoarium*: cell-mouths, so far as I can make out, rather elongated, peristomes not prominent, reverse striated?

Formation. Imbedded in volcanic ash, probably of the age of the Bala rocks.

Locality. Middleton Hill, near Welshpool.

Cabinet. J. B. Morgan, Esq., Welshpool; one specimen.

This beautiful specimen, which I have drawn magnified about four diameters, is buried in volcanic ash, which is so friable that it breaks away with the least touch. It is very certain that it is the reverse surface that is exposed; but towards the bottom the thickened branch is broken away, and the cells are exposed. The appearance of the branch at this part is shown in fig. 2, B; but when more highly magnified the arrangement of the cells is seen to be pretty regular, and is shown in fig. 2, C. By extracting a minute fragment of the specimen from the matrix, I have been able to expose the poriferous surface, and this is shown in fig. 2, D. So far as I am able to judge by carefully manipulating this delicate fossil, I can almost confidently assert that the species now described differs considerably from the species previously described by myself *

* Quart. Journ. Geol. Soc. vol. xxxviii. p. 60.

and by Mr. Shrubsole * as *Thamniscus crassus*, from the Wenlock Shales and Dudley Limestone.

Referring again to Prof. Nicholson's paper on "New Palæozoic Polyzoa" (*op. cit.*), I wish to draw attention to two of his figures, because these have some resemblance to the present species. Of figs. 3 and 3 *a* in pl. ii. the author says (explanation of pl. *op. cit.* p. 5), "Fig. 3.—*Fenestella Davidsoni*, a small portion of the non-poriferous side of the natural size. Fig. 3 *a*.—Portion of the same enlarged." Both these figures appear to me to be portions of a free-branching *Thamniscus*. There are no fenestrules or dissepiments. Figs. 3 *b* and 3 *c* of the same plate, "portions of the poriferous side of another specimen" (Nich.), belong, so far as I can judge from the figures, to a different species, apparently a true *Fenestella*. I know Prof. Nicholson will receive my remarks in the spirit in which they are offered; my only desire in criticizing his labours is to bring out all the information that is possible in describing forms still older than, but apparently generically related to, the Hamilton species described as *Fenestella Davidsoni* by Nicholson.

Range of Lower-Silurian *Phylloporæ*.

1. *Phyllopora*. Lower Llandeilo. Cat. p. 20†.
2. —— *Hisingeri*, McCoy. Caradoc. Cat. p. 44. From several localities.
3. —— *ornata*, MS. (Wyatt-Edgell). Caradoc. Cat. p. 44.
4. —— *tumida*, Vine. Caradoc (fig. 1, above).
5. —— *variolata*, Ulrich. Cincinnati Group.
6. —— *clathrata*, Miller and Dyer. Cincinnati Group.
7. —— *trentonensis*, Nicholson. Trenton, L. Ontario.
8. —— sp., Lower Llandovery. Cat. p. 64.

I give the whole of the forms known to me; but I would advise the examination especially of those numbered 1, 3, and 8, in the above list. The Upper Silurian *Phylloporæ* merit full description and illustration; but unhappily the really good specimens are not in my keeping, although ample material is in existence in the cabinets of others for the purpose suggested.

Lower and Upper Silurian Thamniscidæ.

1. *Thamniscus antiquus*, Vine. Age ?, Bala beds (fig. 2, above).
2. —— *crassus*, Lonsdale. Wenlock Shale, Dudley Limestone.
3. —— *variolata*, Hall. Lower Helderberg‡.
4. —— *nysa*, Hall. Lower Helderberg.
5. —— *nysa*, variety, Hall. Lower Helderberg.
6. —— *fruticella*, Hall. Lower Helderberg.
7. —— ? *cisseis*, Hall. Lower Helderberg.

* Quart. Journ. Geol. Soc. vol. xxxviii. p. 344.

† Mus. Pract. Geol. Catalogue. Silurian fossils, 1878.

‡ Corals and Bryozoans of the Lower-Helderberg group, by James Hall. Albany, 1880, pp. 37 & 38.

Note on LICHENOPORA PAUCIPORA, *Vine.* (Quart. Journ. Geol. Soc. vol. xl. p. 853.)

Immediately after the publication of my "Notes on Cretaceous Lichenoporidæ," Mr. Thomas Jesson, F.G.S., of Pulborough, wrote me respecting *L. paucipora*, Vine. Mr. Jesson says that it was he who forwarded to Prof. Duncan the specimens described, and that the fossils were found in washings from the coprolite-bed near Cambridge. In all probability Prof. Duncan had mislaid Mr. Jesson's letter sent in with the fossils, and I am glad to be able to add the locality to the description of the species.

DISCUSSION.

Dr. HINDE remarked that it was impossible to discuss the contents of such a paper as this without having either specimens or good figures to refer to, and he protested against descriptive palæontological papers being read before the Society without such adjuncts.

The CHAIRMAN (Mr. Carruthers) agreed with Dr. Hinde that it was very desirable that specimens should be exhibited if possible, but at the same time it seemed to him that the present paper had been carefully drawn up and would prove useful.

16. *The* Boulder-Clays *of* Lincolnshire. *Their* Geographical Range *and* Relative Age. By A. J. Jukes-Browne, Esq., B.A., F.G.S. (Read January 28, 1885.)

(Communicated by permission of the Director-General of the Geological Survey.)

Introduction.

When I commenced the survey of East Lincolnshire, in 1877, the only connected account of the Boulder-clay was to be found in the well-known paper by Messrs Wood and Rome *; and up to 1879, when I wrote a paper "On the Southerly Extension of the Hessle Boulder-clay in Lincolnshire" †, I saw no reason for doubting the propriety of their classification.

The mapping of these clays by myself and colleagues during the subsequent progress of the Survey has, however, brought to light many facts which were unknown to Mr. Searles Wood, and has led us to question the accuracy of his interpretation of those facts which were known to him.

The classification of glacial deposits is always a difficult matter, and in Lincolnshire there are special circumstances which make it very difficult to ascertain the relative age of the several masses of Boulder-clay.

Mr. Searles Wood himself, though still adhering to the divisions which he first established, has considerably modified his views with regard to the correlation of the Lincolnshire Boulder-clays. His original classification of the glacial series in East Yorkshire and Lincolnshire, as published in 1868 ‡, was as follows:—

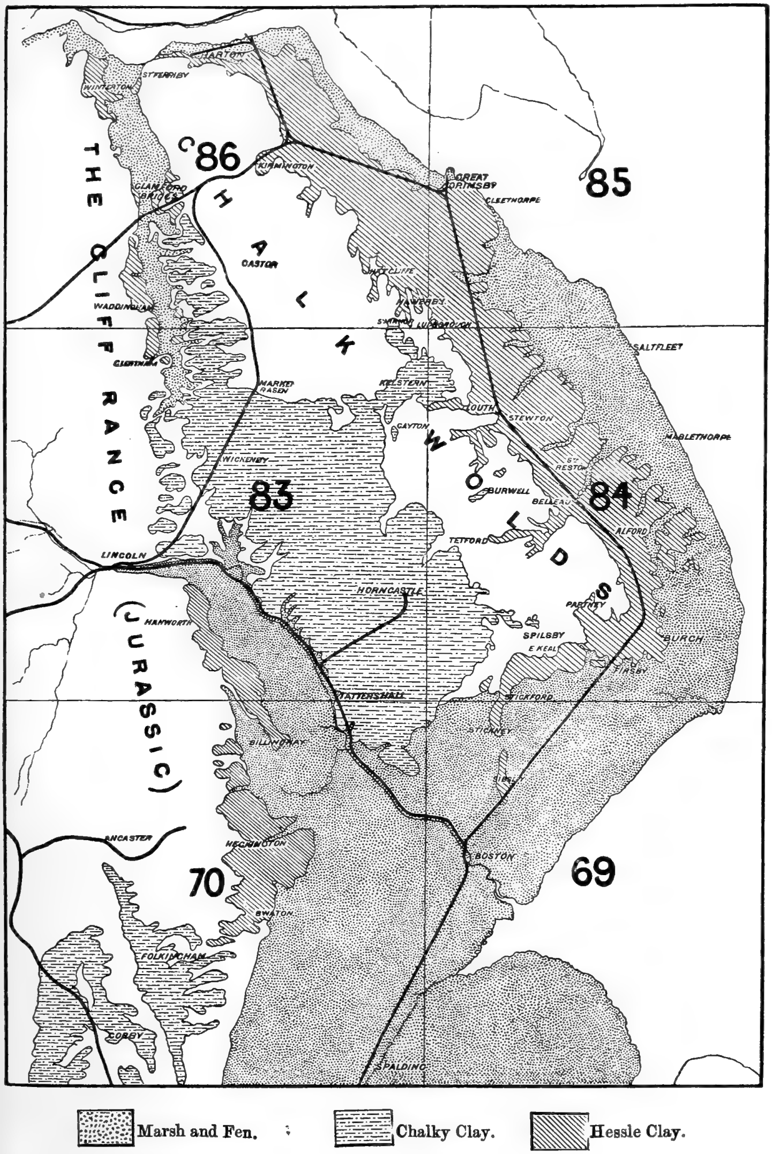
5. Hessle clay.
4. Hessle sand and gravel.
3. Purple clay.
2. Sands and gravels.
1. Basement clay.

He then regarded the Basement clay as the equivalent of the East Anglian Upper Boulder-clay, and considered the overlying Purple and Hessle Clays as newer than any part of this southern Chalky Boulder-clay. In his last paper (1880) he takes a different view, and appears to look upon the Basement and Purple Clays as together representing the whole East Anglian series §.

In both memoirs he insists upon the existence of a great break at the base of the Hessle beds, and even goes so far as to exclude these beds from the glacial series altogether, grouping them as Post-glacial, because they are bedded into the Wold valleys and because at one locality they happen to contain the shell *Cyrena fluminalis*.

* Quart. Journ. Geol. Soc. vol. xxiv. p. 146. † *Op. cit.* vol. xxxv. p. 397.
‡ *Loc. cit.*
§ Quart. Journ. Geol. Soc. vol. xxxvi. p. 527.

Fig. 1.—*Sketch-Map of Lincolnshire, showing the range of the Boulder-clays: reduced from the maps of the Geological Survey.* (Scale about 12 miles to an inch.)



I propose, therefore, to set down some of the evidence which I have obtained during the last six years, in order that the present state of the case may be properly apprehended, and that the links which are wanting in the chain of evidence, and the difficulties which call for explanation, may be clearly perceived.

No one who studies the Lincolnshire Boulder-clays can fail to be struck with the great differences between the two principal types of glacial clay which occur in the county; they fall naturally into two groups—a brown series and a grey or blue series, which are not only lithologically different, but also to a great extent geographically separate. It will perhaps clear the ground if I commence by briefly sketching the range of these two types of Boulder-clay, leaving their points of contact to be considered afterwards. The relations of the two members of the "brown series," namely the Purple and Hessle Clays, will next be discussed; and in conclusion such inferences will be drawn as appear to be warranted by the facts described *.

§ 1. *The Range or superficial Extension of the Chalky Boulder-clay.*

This type of Boulder-clay only occurs in the southern, central, and western parts of the county. In the south-west, about Corby and Ponton, it is generally of a light grey or greyish-blue colour, full of chalk and oolitic débris; beneath the Fens and northward along the central valley it is usually of a deep blue or blue-grey; but eastward as it nears the Chalk Wolds it becomes lighter and lighter, finally passing into an intensely chalky clay or marl of a pure white or yellowish-white tint.

There can, I think, be little doubt that these grey-blue and white Boulder-clays form part of the great sheet which spreads over the eastern Midlands, and which appears to be continuous with what has been termed by Mr. Searles Wood the Chalky Boulder-clay or Upper Boulder-clay of East Anglia.

The mapping of sheets 70 and 83 † has disclosed certain peculiarities in the lie of this Boulder-clay which deserve attention. In sheet 64 (south of sheet 70) spreads of Boulder-clay occur both on the lowest and on the highest levels; and some of these entering sheet 70 extend northward along the high ground by Great Ponton and Somerby to Kelby, a village about two miles S.E. of Ancaster. But from Ancaster and Sleaford northward to Lincoln no trace of this clay has been found along any part of the tract occupied by the outcrops of the Jurassic strata. Again from Lincoln northward no Boulder-clay is found along the higher ground, though it is

* For a full description of the Lincolnshire Boulder-clays and of the sections observed during the progress of the Geological Survey the reader is referred to the explanations of sheets 70, 83, 84, 85, and 86, which are now in course of publication. In the following pages only a few sections are described as specially illustrating the relations of the several clays, and the paper is designed to convey such theoretical conclusions as do not find a place in the Survey Memoirs. These conclusions are not, however, to be taken as expressing the general opinion of the officers of the Survey, but are my own personal views.

† These numbers refer to the sheets of the Ordnance Survey map, and their limits are shown on the map accompanying this paper.

continuous on the eastern flank and soon begins to set in on the western flank.

The great sheet which slopes northward through Cambridgeshire and caps the islands of Ely and March dips beneath the Fen-level along a line running south of Crowland and Wisbech and continues to underlie the plain of the Fenland by Spalding, Donington, and Boston. It may have been, and probably was, connected with that which spreads over the high land in the south part of sheet 70, but it is now disconnected by erosion along the Fen border. Unlike the high-level mass, it does not terminate in the latitude of Ancaster, but appears to run northward below the Fens bordering the Witham, emerging along their eastern border by Tattershall, Kirkstead, and Bardney. Thence this Chalky Boulder-clay spreads northward through Wragby and Market Rasen to Brigg, and eastward to Horncastle and the high ground between the valleys of the Bain and the Steeping in sheet 84.

It also sends a tongue-like prolongation north-eastwards, from Hainton and South Willingham, across the escarpments of the Lower Neocomian and the Chalk, by Gayton-le-Wold and Brough-on-Bain, up on to the summit of the Chalk Wolds near Kelstern and Elkington to the north-west of Louth. Near Gayton the Boulder-clay and associated gravels are seen to be bedded against the slope of the Chalk escarpment, showing that this escarpment had retired to its present position in pre-glacial times. The height of the ground near Kelstern is about 400 feet above datum-level.

Another important point in connection with the distribution of this Boulder-clay is this, that with the exception of the tongue above mentioned and a small outlying patch to the southward, it is not found anywhere along the broad tract of the Chalk Wolds from their commencement near Candlesby to their intersection by the Humber. This is the more remarkable because this clay caps the high ground formed by the Lower Neocomian escarpment near Greetham, Fulletby, and Scamblesby, which is as high as, if not higher than, the corresponding part of the Chalk escarpment. Still the occurrence of the single outlier near Maidenwell, and the fact of its climbing on to the Wolds by Kelstern, seem to indicate that the Boulder-clay once had a continuous extension over these hills. We are consequently obliged to conclude either that the Wold hills have been in some way exposed to more severe and long-continued detrition than the rest of the county, including the Neocomian ridge, or else that the amount of Boulder-clay originally deposited on the Chalk hills was very much less than elsewhere. It is very probable that its thickness was less on these hills, and I have shown in previous papers that erosive agencies have been very active over this tract.

§ 2. *The Range of Brown Boulder-Clays.*

The Eastern Border.—In describing these clays and their mode of occurrence it will be convenient to commence on the north border of the Fenland, near Firsby, a station on the Great Northern line;

and for details of the sections visible in this neighbourhood, I may refer to my paper "On the Southerly Extension of the Hessle Boulder-Clay in Lincolnshire"*. The map accompanying that paper also shows the manner in which this clay, together with the underlying Purple Clay, stretches northward, and forms a broad tract of undulating land between the Chalk Wolds and the eastern marshes. That map, however, having been drawn before the boundaries of the Boulder-clay had been accurately mapped north of Alford, it is necessary to give some account of its inland boundary from this point, and the map (p. 115) will enable the reader to follow the ensuing description.

This boundary, to the west of Alford, is almost a straight line; the clay ends abruptly against the rise of the Chalk Wolds, and the depth of the clay increases with the rise of the ground from Alford towards the hills. Thus near Alford the usual depth of the Boulder-clay is about sixty feet, but near Rigsby a well was sunk within a furlong of the boundary-line, and passed through ninety feet of clay without piercing it. These facts show that the plain of Chalk on which the Boulder-clay rests is nearly horizontal, and extends up to the foot of the Wolds. They also seem to indicate that the clays are banked up against a buried cliff of chalk. This sharp boundary-line continues north-westward for about two miles, till it is broken by the outlet of the Calceby beck between Aby and Belleau. Here there is an extensive bed of gravel, intercalated apparently between an Upper and Lower Boulder-clay, and evidently a beach-formation, containing broken marine shells in the sandy beds, and rolled pebbles of chalk, pierced by *Pholades*, in the gravel beds. At South Thoresby there are two beds of gravel, separated by a layer of clay, about 20 feet thick, and the same is the case at Claythorpe station.

At and beyond Belleau the Boulder-clay overrides the cliff or slope of the Chalk, and for some distance caps the ridge which runs through Burwell Park. From this place to the neighbourhood of Louth, the boundary is very irregular, outliers of Boulder-clay occurring on the highest hills, and tongues of the same clay occupying the bottoms of the valleys which ramify through the Wolds. The height to which the Boulder-clay here ascends must be nearly 300 feet; but in colour and general appearance it is precisely the same as that found near the surface of the lower ground.

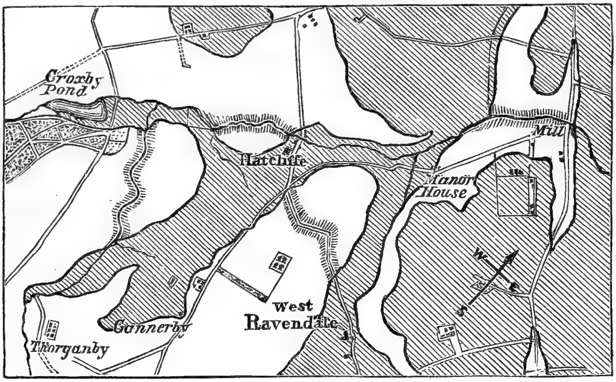
North of Louth, for a short distance, the border of the Chalk Wolds is similarly smothered in Boulder-clay; but near Fotherby the boundary descends to a lower level and becomes again sharp and clear. Striking N.N.W., and only interrupted by tongues thrust up the older valleys, it passes into sheet 86, between Wyham and Hawerby. At the latter place the boundary-line appears to pass between the church and "the Hall" occupied by Mr. Harness; this gentleman informed me that a well had been sunk in his yard to a depth of 156 feet without meeting anything else than clay. As chalk comes to the surface at a distance of about 150 yards, there is a very steep slope

* Quart. Journ. Geol. Soc. vol. xxxv. p. 397.

(if not a cliff) of chalk at this place, and probably all along the line of rise from the lower plain to the Wold hills.

At the same time it is clear that the Boulder-clay overrode this cliff-line, and buried a considerable portion of the Wold land to the westward. A thin outlier caps the high ridge between Hawerby and Wold Newton, the summit of which is 382 feet above datum-level; and the same Boulder-clay occupies the valley-bottom which runs northward from Wold Newton to Ravendale.

Fig. 2.—*Plan of the country near Hatcliffe.* (Scale 1 inch to a mile. The ground occupied by Drift is indicated by diagonal shading.)



Near East Ravendale there is direct continuity between the clay in this valley and that outside the chalk ridge; and the mapping east of Hatcliffe (fig. 2) suggests the existence of a cliff-line breached by the battering of ice before or during the deposition of the Boulder-clay. From this locality the brown clays are traceable northward by Laceby and Brocklesby to Barrow and Barton-on-Humber.

Westerly Extension.—From Hessle, on the north side of the Humber, the so-called Hessle Clay sweeps westwards to North Ferriby, and as it is also found on the south side of the river at Barton and near South Ferriby, Mr. Searles Wood justly concluded that it had once filled the great gap in the Wolds through which the Humber flows. But if the Boulder-clay extended through this gap, we should certainly expect to find it on the western side of the Wolds, both north and south of the Humber, at similar low levels. Mr. Searles Wood could not find it, and he suggests some elaborate hypotheses to account for its supposed absence. These, however, are fortunately rendered unnecessary by the simple fact that it is not absent, but present in some force, both to the southward and westward of South Ferriby. It may be seen near Horkstow Bridge, $1\frac{1}{2}$ mile S.W. of Ferriby, and again in the dyke at the east end of Winterton Holme, whence it extends westward to Winterton, and thence northward to Winteringham, and it probably underlies parts of the alluvium of the Ancholme. Along the eastern border of this

alluvium at the base of the Chalk escarpment, runs a terrace of gravel, apparently a continuation of that which overlies the western end of the Hessle Clay at Ferriby cliff. Whether this gravel is of Hessle age is uncertain.

The Hessle Clay, however, has been found again in the neighbourhood of Wrawby and Brigg, and its exposures will be described in the Explanation of Sheet 86. Its character here is much more variable than on the eastern side of the Wolds. Sometimes it is full of stones, and sometimes hardly a pebble can be found in it; occasionally it passes into a laminated sandy loam; in colour, however, it still resembles the typical Hessle Clay, being of a reddish brown streaked and mottled with ashen or bluish grey.

From Brigg it extends southwards, but has only been detected at low levels on either side of the broad valley of the Ancholme. Clays and gravels, apparently belonging to it, have been mapped at Cadney, Hibaldstow, Redbourn Hays, Waddingham and Thornton Carrs, Owersby Carrs, and near Bishop's Bridge, east of Glentham; but in some of these localities it puts on an aspect which is very different from that which it usually presents. It becomes a sticky bluish clay, mottled in some places with yellow or brown, and only containing here and there a rolled pebble of quartzite. In this form it resembled weathered Oxford Clay so greatly, that it was at first overlooked, but mapped in subsequently, after a careful and prolonged examination of the ground by Mr. Ussher and myself. We found that this peculiar clay was everywhere underlain by gravel, and that it sometimes passed into reddish clay, with stones more resembling the ordinary type.

Beyond Bishop's Bridge, to the east of Glentham, it was no longer traceable in the Ancholme valley; but south-west of Market Rasen a reddish brown clay, mottled with grey and containing small flints and pebbles of chalk, sets in at higher levels. This closely overlies the ordinary grey Boulder-clay of the district, and caps the low ridges separating the valleys of the brooks which flow westward to unite in the Langworth beck.

There is a considerable area of such clay west of Faldingworth, and again between Swinthorpe and Wickenby; and sand and sandy gravel are frequently found in connection with it, both above and below. I only saw these beds in a hasty traverse, made last year after the country had been mapped, but found a fair section of them in the railway-cutting west of Wickenby, the succession here being as below:—

	feet.
Sandy soil and sand	3
Red-brown Boulder-clay	1
Yellow sand full of flints, seen for	1
? Grey Boulder-clay below (grassed over)	—

These beds are so thin and so badly exposed, that I could not be certain of their identity with the Hessle Clay, but they are very different from the grey Chalky Boulder-clay which surrounds them. South of this point, over a considerable space, as far as the valley of

the Witham, nothing is known of this brown Boulder-clay, because it has never been looked for; but there can be little doubt that, if looked for, it would be found, because it occurs on the further side of the Witham, and it is not likely to be absent in the intermediate area, unless it has been removed by detrition and erosion.

Crossing the Fens which occupy the ancient estuary of the Witham, we find a strip of Boulder-clay occupying a peculiar position along their south-west border. It has been already mentioned that the ground occupied by the Lower Oolite south of Lincoln is entirely free from Boulder-clay of any sort. The existence of this strip of Boulder-clay along the Fen border was not then spoken of, because there is reason to think that it belongs, not to the Chalky Clay, but to the other series we have been following.

When mapped in 1878, it was supposed to belong to the mass of grey and blue Boulder-clay which comes down to the fen-level on the eastern side; the existence of Purple or Hessle Clay so far westward was not then thought of, and the question of separating the Boulder-clays had not then been raised. My note-book, however, contains a mention of peculiar brown and grey mottled clay, with small fragments of chalk, as seen at Martin Wood near Timberland. I have not had an opportunity of revisiting this, but have little doubt that this clay is of the East-Lincolnshire type.

This ridge of Boulder-clay (which is capped by a remarkable series of quartzitiferous gravel) passes into sheet 70 between Timberland and Thorpe Tilney and becomes a promontory jutting into the Fenland as far as Billinghay. Its western border has, in fact, been cut back by the erosive agencies which have formed the post-glacial valley of the Scroby beck; and there can be little doubt that this Boulder-clay was once continuous from Walcott and Billinghay to the neighbourhood of Anwick and Ewerby.

Of the Boulder-clay of Ewerby I can speak, again, from personal knowledge. By Haverholme Park it is a mottled buff and brown clay, full of small chalk stones, with a gritty or sandy feel, and in every respect like the clays of East Lincolnshire. At Ewerby Thorpe it is of a uniform dull purple-brown colour; but this is exceptional, and to the southward by Howell and Heckington, the buff and grey tints predominate over the brown, though the mottling and sandy admixture remain conspicuous features.

Near Heckington it occupies a tract of ground which is five miles wide, and it passes eastward under the silt of the Fenland. The gravels associated with it and on which stand the villages of Heckington, Great Hale, Little Hale, and Helpringham, all contain rounded pebbles of quartz and quartzite, together with flints and fragments of Jurassic limestones.

Boulder-clay of the same character continues southward by Swaton and Horbling, though here the fen-beds encroach upon and narrow the tract which it occupies. I have not traced it further to the south than Horbling and Stow Green, and here, therefore, further exploration is required with the object of acertaining its southern limit. In appearance it is so different from the grey or

white Chalky Clay of the high lands that its separation therefrom ought not to be a difficult task if it maintains its usual characters; but it is conceivable that if newer than, and banked against, the Chalky Clay the reconstructed material of the latter would give it a different aspect and introduce a source of confusion and difficulty.

If the Boulder-clay which borders the western side of the Fenland is distinct from, and newer than, the bluish-grey clay which occurs on the southern borders, and if both pass beneath the Fens, then the newer clay ought to be found overlying the older clay in the neighbourhood of Boston. The large excavations made for the new docks at Boston last year enabled me to test this expectation. The section I found at the bottom of the dock-basin in November was:—

	feet.
Clay and silt	18
Peat	1
White and grey sands	1
Reddish sand and stones in pockets worn in mottled buff and grey Boulder-clay ... about	6

The Boulder-clay with the reddish sand and gravel in pipes and pockets was similar in appearance to that near the western border of the Fen, just, in fact, such as the surface near Heckington and Hale would present if now submerged and covered by newer deposits. In a deeper trench, between the dock and the river, a dark-blue Boulder-clay was exposed underneath the mottled clay which forms the base of ths dock-section. The line of junction was not clear, but appeared to be a sharp one.

The existence of so-called Hessle Clay beneath Boston, anticipated by me in 1879 *, is thus confirmed, though its thickness is but small. The upper portion has probably been carried away by erosion, so that only the basement part remains.

My reason for suspecting the existence of this clay beneath Boston was that it occurs in the form of an island at the surface near Sibsey, about five miles to the N.N.E. Here and at Stickney, still further north, the clay is of a uniform purple-brown colour, this being apparently the tint of the upper portion of the "brown-clay series" in the Fen district †.

From Stickney this clay continues by Stickford to the northern border of the Fenland, of which it forms the margin by Keal Coates, Toynton, and Little Steeping to Firsby, where we commenced this description of its range. This ground was described in the paper already referred to; but there is one point to which I desire to recall attention: this is the existence of sand-banks along the northern edge of the Boulder-clay tract, where it is banked up against the slope of the Kimmeridge Clay. This bank forms a kind of terrace at the foot of these hills, and appears to indicate a shore-line. This is of the greater importance, because the original margin of the

* Quart. Journ. Geol. Soc. vol. xxxv. p. 420.

† These clays may therefore belong to the Purple and not to the Hessle Clay.

brown Boulder-clays has in most places been destroyed by post-glacial detrition. The only other locality known to me where beach-deposits contemporaneous with the upper portion of the brown clay occur is near Kirmington, in sheet 86. These have been mapped and investigated by Mr. C. Reid, and will be described by him in the explanation of that sheet. They are interesting as containing a large marine fauna.

There is also another point of interest in connection with the distribution of the brown clay round the Fen borders. In 1879 I drew attention to the peculiar way in which the newer Boulder-clays (then supposed to be Hessle Clay only) terminated southwards in East Lincolnshire*. Leaving the Fen border at Stickford, the brown clay is prolonged southwards in a long ridge or bank by Stickney and Sibsey for a distance of seven miles; and while the Fens on the east side of this bank are underlain by the same Boulder-clay, those on the west side rest directly on Kimmeridge Clay or on the older Boulder-clay which comes in further west.

This struck me at the time as a fact which was both remarkable and difficult of explanation; for if the contours of this part of Lincolnshire during the formation of the newer Boulder-clay were anything like what they are now, it is hard to conceive any valid reason why this clay should be so peculiarly and partially distributed; why it does not continue to form a bordering plateau westward from Stickford, as it does to the eastward of that place and along the east side of the Chalk Wolds.

Not only is the newer Boulder-clay absent from Stickford to Tattershall, but no sign of it has ever been discovered along the eastern side of the Witham level from Tattershall to Lincoln, although in the present paper I have described a continuous strip of this clay as bordering the western side of this level from Billinghay to and beyond Hanworth Booths.

I think we may infer from these facts that the contours of the whole district lying to the east of the Witham level, and along the Fen border as far as Hagnaby beck, have been greatly altered in post-glacial times, that is, since the formation of the newer Boulder-clay. The widespread deposits of gravel and sand of the lower parts of the tract in question demonstrate that it has suffered great erosion and detrition in post-glacial times; so that altogether it seems probable that, at the time when the newer Boulder-clay was formed, this tract was occupied by a mass of the older Boulder-clay, rising above the level at which the newer clay was laid down in the Fen district, and forming a promontory which jutted southwards over what is now termed the West Fen.

On this supposition the existence of the curious ridge of Boulder-clay running through Stickney and Sibsey finds a natural explanation; for if there was originally higher ground to the west of this ridge, it may be regarded simply as a continuation of the bank formed against the old shore-line below Toynton and Keal (see

* See Quart. Journ. Geol. Soc. vol. xxxv. p. 397.

p. 122). This is, in fact, the conclusion at which I arrived in my former paper *.

Assuming also that the trough of the Witham estuary then lay a little to the west of its present course, and that it was filled up from side to side with the brown Boulder-clays, like that of the Humber estuary, we may regard the strip of newer Boulder-clay which runs from Billinghay to Nocton and Hanworth as occupying the western half of this old trough, and may suppose that the eastern half of the clay-filled trough has been removed by post-glacial erosion.

This erosion was no doubt partly effected by the river flowing through the Lincoln gorge and impinging upon its left bank; and it is interesting to note that this tendency to impinge upon the left bank is maintained by the modern river Witham, which hugs the eastern edge of the fen-level all the way from Bardney to Tattershall. The erosion of this eastern side was doubtless assisted by the action of the tributary streams flowing off the clay-tracts to the eastward, which would naturally have a greater volume and velocity than those which drained the limestone country to the westward. The Hagnaby beck rising near Bolingbroke has likewise done its share of the work by attacking the promontory of older Boulder-clay on the other side.

There is, therefore, nothing to militate against the supposition of such a promontory, but, on the contrary, all the facts known to me tell in favour of its existence; I think, therefore, it is a feature which must be introduced into any picture of the Fenland during early post-glacial times.

§ 3. *Points of Contact between the two Series of Boulder-clays.*

In East Lincolnshire there are only three localities where the Brown Boulder-clay comes into contact with the White Boulder-clay.

The first of these is at Maidenwell, five miles south of Louth. Here, at a height of about 400 feet above sea-level, occurs an outlying patch of white Chalky Boulder-clay capped with flint-gravel. The same clay also continues down the slope to Maidenwell farm, to the east of which a second patch of gravel occurs, probably overlying the white clay, but passing eastward into or under a mass of brown clay. No good sections are here to be found.

The second locality is near Welton, about three miles west of Louth. Here clay of the Hessle type, overlying a great depth of gravel and exposed in good sections, appears to be banked against a slope of white Chalky Boulder-clay. Near the line of junction a soft, silty, yellowish clay, or calcareous loam, occurs; and the true relations of the two series might easily be exposed by excavating a short trench down the slope at this spot.

The third locality is near Wold Newton, in sheet 86. The Chalky Boulder-clay enters the sheet S.W. of this village, and ends in three spurs; the central one of these descends to a lower level than the others, and either passes under or into a brownish clay; but the

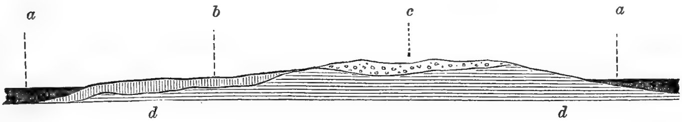
* *Loc. cit.* p. 409.

entire absence of even ditch-sections prevented my coming to any conclusion on this point.

The appearances at these three localities being not unfavourable to the supposition that the brown clays passed into chalky clay, taken together with the fact of the former clay occurring at so great a height on the Wold as nearly 400 feet, inclined me to the belief that there was no great separation in time between the formation of the two series. It was not, therefore, till last year (1883) that I recurred to the opposite opinion, in consequence of finding evidence on the west side of the Wolds which forced me to regard the brown clays of that district as belonging to a much more recent period than the blue and chalky clays. This evidence may be briefly recapitulated as follows:—

1. The position of the red-brown clays near Brigg resting against ridges of Jurassic clay, which are capped by outliers of Chalky Boulder-clay (as in fig. 3), the two clays being very different in

Fig. 3.—*Section through Low Barf, S.E. of Brigg.*
(Horizontal scale: 2 inches to a mile.)



a. Alluvium. *b.* Red Clay, *c.* Chalky Clay. *d.* Oxford Clay.

appearance, and the former occupying valleys which appear to have been eroded out of a surface composed of Oxford Clay overspread by a sheet of Chalky Boulder-clay.

2. The fact that a red-brown clay of similar type actually rests upon a continuation of the older Boulder-clay in the district between Market Rasen and Langworth.

3. The manner in which the mottled clays separate themselves from the blue Boulder-clay and from a terrace or narrow tract along the western border of the Fenland, between it and the highland, just as they do between the marshland of East Lincolnshire and the Chalk Wolds.

To these considerations may be added the following:—

4. The actual superposition of the mottled clay on the blue Boulder-clay at Boston.

5. The relative positions of the two clays along the north border of the Fens by East and West Keal, where the Brown Clay is banked against the slope of hills capped with Chalky Boulder-clay*.

6. The fact that, while both Boulder-clays are found at the same level south of Revesby, they each retain their distinctive colours and characters and occur in separate areas.

* See Section in Quart. Journ. Geol. Soc. vol. xxxv. p. 405.

§ 4. *The Value of the Divisional Line between the Purple and Hessle Clays.*

I will now assume what appears to be the outcome of the preceding facts, namely, that some or all of the East Lincolnshire Boulder-clay is newer than the Upper Boulder-clay of East Anglia. Whether all of it be of such newer date is still open to question; and this brings me to discuss the distinction which has been made between the Purple and Hessle Clays.

All the sections which have come under my notice (showing the junction of these two portions of the Boulder-clay series) I have examined with a special view to this question; and I may state at the outset that I think Mr. Searles Wood has greatly exaggerated the importance of this line of division.

I make a few extracts from my notebook in support of this opinion.

At South-Reston brickyard, 5 miles S.E. of Louth, an upper and lower clay are clearly visible, the upper being reddish brown streaked with grey, and including near its base a lenticular layer of brown sand; the lower is of a dark purple brown, without streaks: these beds, however, are only separated by two feet of brownish-purple laminated loam, which rests evenly on the lower clay, and the whole forms an unbroken succession.

At Stewton brickyard, two miles east of Louth, the following section was visible in 1882:—

	feet.
Loamy soil	2
Reddish brown clay, with lenticular seams of loamy sand and silt	4
Yellowish-brown sand	$\frac{1}{2}$–$1\frac{1}{2}$
Dark purplish-brown clay, seen for	6

The sand-bed includes patches or layers of Boulder-clay, and appears to be intimately connected with the clays above and below. At one place it thickens to 2 feet, and has a layer of small pebbles at the base, but it is certainly not an important line of division. The sides of the joint-planes and cracks in the upper clay are ash-coloured, but those in the lower are in places stained with dark greyish-blue, which would probably become ash-grey if exposed more to atmospheric action; moreover, the top of the lower clay immediately underlying the sand is of the same reddish tint as the upper clay. This seems to suggest that the colours of the upper clay are due to alteration by surface agencies.

Both here and at Reston the upper clay is said to burn red in bricks, while the lower clay burns white; can it be that there is more oxide of iron in the former? and is the purple colour of the lower clay partly due to carbonate of iron?

The brickyard in James Street, Louth, shows:—

	feet.
Reddish clay (grey-streaked), with a base of hard sandy and stony loam	14
Purple-brown clay, with fewer stones	10

The junction here is level, and no signs of erosion are visible. Further, in another brickyard south of the town, a similar reddish clay passes downward into purple-brown clay without any kind of separation.

I also found the same complete passage from one kind of clay into the other, shown in a brickyard at Ludborough; the section here was:—

	feet.
Clean, stiff, loamy clay	2
Stratified sand, with layers of loam	5
Reddish-brown clay with grey streaks, passing down into purple-brown clay with bluish streaks and then into uniform bluish-brown clay	13

At Cleethorpes, where Mr. Searles Wood himself says that the Purple Clay is seen capped with Hessle Clay along the cliffs, the appearances are in reality similar to those above described at Ludborough. Near the steps which lead down on to the shore the cliff is about 30 feet high; at its base there is about 7 feet of purplish clay passing upward into hard reddish clay streaked and mottled with light grey; along the horizon of passage there is an appearance of stratification, but no well-marked line of division. The whole forms one solid mass traversed by the same planes of jointing or fracture.

When traced in either direction, small lenticular beds of yellow sand may be found, some distinctly within the limits of the reddish clay, some about the horizon of passage, but all of them discontinuous.

I may add that my colleagues, Messrs. Reid and Strahan, agree with me as regards the complete passage from one clay to the other at Cleethorpes.

I have not personally visited the Holderness-coast sections; but Mr. Lamplugh, who studied them closely and continuously for some years, informs me that there is nothing which exactly corresponds to Mr. S. Wood's representation of the Hessle Clay, "though there is an uppermost Boulder-clay, generally reddish brown in colour, which may be traced for miles along the coast." This reddish clay, however, is as well developed to the north of Flamborough Head as it is to the south of that point; while the Hessle Clay, as defined by Mr. S. Wood, does not reach so far northward as Bridlington.

In a recent letter to me, Mr. Lamplugh says:—"I do not believe in any important unconformity between this clay and the beds below it, and the more I see of our glacial sections, the more disinclined am I to believe in any great break in the sequence of events. The best-marked unconformity that I know of is at the base of the Purple Clay in this neighbourhood [Bridlington]; but at Dimlington even this break is not nearly so clear."

This line of erosion did not escape Mr. S. Wood; he says that the basement clay "is overlapped in every direction by another thick bed of Boulder-clay, to which, in most of its exposures, it presents a very denuded surface, rising up beneath it in bosses, and in some

places divided from it by the beds marked *b* (sands and gravel)"*. He adds that though sometimes it is difficult to say where one clay ends and the other begins, in other places the division is very distinct.

Now the facts I have adduced appear to me sufficient of themselves to invalidate Mr. S. Wood's classification, and, as a necessary consequence, to destroy the superstructure of theory which he has built upon it. Mr. Wood hardly seems to recognize the difference between widespread unconformity and local contemporaneous erosion. If the succession were broken in the manner assumed by Mr. Wood, and if the interval between the formation of the Purple Clay and the Hessle gravel were of such length and importance that it could be taken as the line of division between the Glacial and Post-glacial periods, then this break must be a widespread one, and must be universal throughout the east Yorkshire and Lincolnshire area.

But if, on the contrary, it can be proved that at two or three localities there is a complete passage from one clay into the other, then it is clear that the break is not a universal one, and the line of division becomes one of comparative insignificance.

In the face of such sections as those at Cleethorpes, Louth, and Ludborough, where no break exists, it is useless to multiply instances where the clays are separated by beds of gravel and sand, and where some local erosion appears to have taken place. Still more unreasonable is it to argue from these local appearances, and from the occurrence of *Cyrena fluminalis* in the gravels, that the Hessle beds should not be regarded as Glacial, but as Post-glacial deposits.

I can see no valid reason why the whole series of Boulder-clays and gravels in east Yorkshire and Lincolnshire should not be classified as Glacial; and I look upon those above the basement clay as forming one continuous series, so far as any series of Glacial deposits can be called continuous. That cases of local erosion by currents should occur, and that beds of gravel and sand should be intercalated between the Boulder-clays, are natural incidents in a series of deposits which have been formed near coast-lines by the agency of marine ice; and my conviction that these Boulder-clays have been so formed has only been deepened by my recent experiences and observations.

§ 5. *Conclusions.*

In section 3, we came to the conclusion that the brown and mottled clays of the Fen-border and the Ancholme valley were newer than the Chalky Boulder-clay of those districts; further that there was a decided break and an apparent unconformity between the two groups. In the last section I denied the existence of any break in the Brown-clay series of East Lincolnshire (*i.e.* the Purple and Hessle Clays), and showed that Mr. Lamplugh holds the same opinion with regard to the continuity of this group along the Holderness coast. It seems therefore only reasonable to conclude in the first place that the Glacial beds found on the west and on the

* Quart. Journ. Geol. Soc. vol. xxiv. p. 147.

east of the Lincolnshire Wolds do not form parallel series. If the Chalky Boulder-clay and the Purple Boulder-clay were correlatives, we should be confronted with the anomaly of a continuous succession existing on one side of the Wolds, while there is a discontinuous succession on the other.

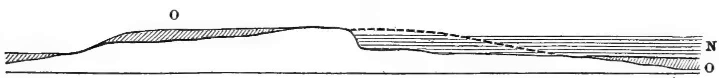
Assuming that they are not parallel series, and also supposing for the moment that the brown clays on either side of the dividing ridge in Lincolnshire are complete correlatives, then it is the Chalky Clay which is unrepresented on the eastern side. Now in East Lincolnshire the base cannot be seen; but in Yorkshire there is a grey and chalky Basement-clay (beneath the Purple-clay) which was originally regarded by Messrs. Wood and Rome as the equivalent of the Upper Glacial-clay of East Anglia. Moreover we have Mr. Lamplugh's testimony as to the appearance of a break with more or less unconformity between this Basement-clay and the overlying Purple-clay.

I have little hesitation therefore in considering the Basement-clay of Holderness the sole representative of the grey and white Boulder-clays of Lincolnshire, and in regarding the overlying beds of Brown Boulder-clay, with their associated loams, sands, and gravels, as newer and higher members of the great Glacial series.

This conclusion differs from that recently enunciated* by Mr. Searles Wood, but it is not the only point on which his earlier views appear to me to be sounder that those he has subsequently elaborated.

The position of the chalky "Basement-clay" at and below the sea-level in Holderness, while on the Wolds of Lincolnshire it rises to a great height above the sea, offers no difficulty to this correlation; because the same clay occurs at nearly as low a level on the west side of those Wolds. I apprehend, indeed, that the Chalk Wolds were at one time completely mantled by the "Chalky Clay" from side to side; just as the Jurassic ridge was clearly so covered in Rutland and South Lincolnshire.

Fig. 4.—*Diagram to show the Erosion of the Chalk Wolds.*



O, older Boulder-clay. N, newer Boulder-clay.

The available evidence seems to indicate that the eastern slope of the Chalk Wolds was invaded and destroyed by marine erosion during a subsequent submergence, at or immediately before the time when the newer (brown) clays were deposited, and that these were laid down upon the plane of erosion so formed. This idea is expressed in fig. 4, which is not a section along any particular line, but only a diagrammatic representation of the relations above suggested, the plane of erosion being partly across the Basement-

* Quart. Journ. Geol. Soc. vol. xxxvi. p. 527, and xxxviii. p. 712.

clay and partly across the Chalk, and the broken line indicating the original slope of the latter.

There remains another question to be considered, and this is the importance or magnitude of the break above indicated between the Chalky and Purple Boulder-clays. This break would appear to be greater in the valley of the Ancholme than in Holderness, and it is quite possible that part of the Purple Clay may be absent from the former district. It is at any rate very likely that there was a more continuous formation of Boulder-clays on the eastern than on the western side of the Wolds, since the ice which formed them clearly came from the east and north-east. It is also not improbable that current-erosion may have been going on in the one locality while deposition was taking place in the other.

The thickness of the Hessle and Purple Clays on the eastern side of the Wolds is certainly greater than that of the similar clay in the valley of the Ancholme, and this also is in favour of the supposition that some of the Purple Clay is wanting in the latter district. On the borders of the estuary of the Humber the Purple Clay certainly thins out westward, and allows the Hessle beds to rest on the Chalk. The clay about Winterton resembles the Purple Clay, but that to the southward near Brigg is certainly more of the Hessle type.

Without discussing the physical conditions of the Glacial period or the exact manner in which Boulder-clays were formed, I will only indicate the general sequence of events which a consideration of all the facts known to me has suggested.

To my mind the frequent occurrence of stratified beds, and the actual existence of marine shells at more than one horizon in the Brown-clay series, is sufficient evidence that the area of deposition was essentially marine, and that the materials were borne by marine ice.

The basement beds of the Glacial series of Norfolk give indications of continued depression and a gradual deepening sea, till the whole of eastern and midland England was submerged, and Chalky Boulder-clay was spread like a sheet over the whole surface.

This submergence, one of at least 600 feet, must have tended to ameliorate the climate, and to cut off the supply of Boulder-clay. Eventually if the direction of the earth-movement was reversed and gradual elevation ensued, surfaces of the grey Chalky Boulder-clay would be exposed, first to current-erosion, and then to subaerial detrition.

With the partial upheaval of the land, however, glacial conditions would return; Boulder-clay would again be formed, and this for some reason seems to have been generally of a purple-brown colour. It was formed more continuously on the eastern side of the Wolds than on the western; but the Wold hills may only have been at this epoch a submarine ridge, or a peninsula of very slight elevation. If the Wolds were above water during the formation of the Purple Clays, there must have been another movement of depression so as to allow the Hessle Clay to be deposited on surfaces which are now nearly 400 feet above the sea. The extension of shore-deposits with

marine shells in North Lincolnshire to levels of about 200 feet may be evidence of this depression. During this submergence the glacial conditions seem to have passed away, and the land was gradually and finally reelevated.

We may, with Mr. Searles Wood, call the two epochs when thick masses of Boulder-clay were formed, the periods of major and minor glaciation ; but the latter would for me include the formation of the Purple Clay. It is, indeed, this point which I wish to bring out in a strong light: the paragraphs I have just written are purely theoretical and may not really represent anything like the actual sequence of events ; but my statement of the close connection between the Purple and Hessle Clays rests upon personal observation and not upon theoretical grounds. What, therefore, I chiefly insist upon is this, that if there is any one great break in the Glacial series, corresponding to a decided change in physical conditions, this break is not at the base of the Hessle beds, where Mr. Searles Wood puts it, but at the base of the Purple Clay in the Holderness section.

I do not propose to do away with the terms Hessle and Purple Clay, because they may be useful as indicating certain horizons in the Brown-clay group. I only wish to correct what appears to me an error in the accepted classification of the Glacial series, and to degrade the Hessle Clay from a position of primary importance to one of secondary or perhaps even of third-rate rank.

I would simply tabulate the Glacial series as below :—

	Lincolnshire.	Yorkshire.
Newer Glacial	Hessle Clay. Purple Clay.	Hessle Clay. Purple Clay.
Older Glacial	Chalky Clay. Cromer Series (including Middle Sands).	Basement Clay.

Discussion.

Mr. Ussher expressed his agreement with the views of the author, so far as the Brigg section is concerned. He had been greatly indebted to the author in arriving at correct ideas on the relation of the Boulder-clays while mapping that district.

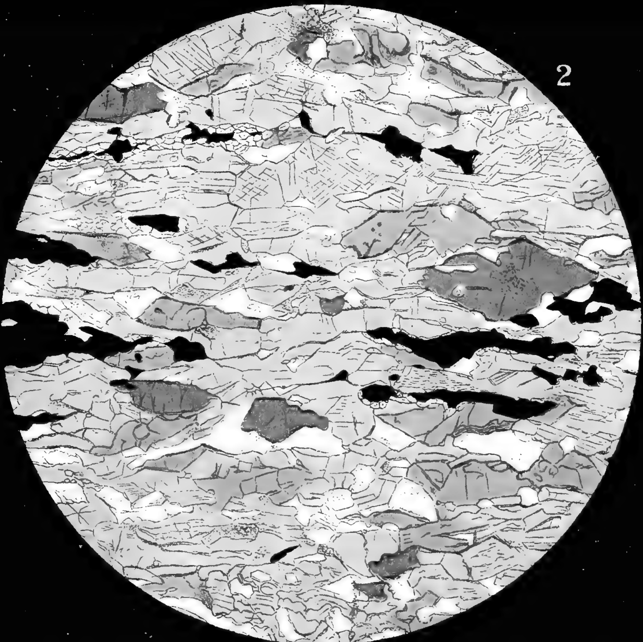
Mr. C. Reid had surveyed part of North Lincolnshire and Holderness. He thought that the Hessle Clay, at Hessle, is only a weathered and decalcified Boulder-clay, and it was unsafe to correlate it with the beds at Kelsey Hill or on the coast. He insisted that the different colours of the Boulder-clays and the absence of chalk from them were frequently due to weathering.

Mr. De Rance asked the last speaker if the shells in the Boulder-clays were similar in type to those found in the intercalated sands. He wished to know if there were any real evidence of intercalation of a fauna characteristic of a milder climate than that indicated by the shells of the Boulder-clay.

Mr. C. Reid replied that there were only fragments of shell in the Boulder-clay.

Mr. Topley remarked that differences in opinion on these theoretical questions were naturally entertained by different members of the Survey. He suggested that the differences between the Boulder-clays on the two sides of the Chalk Wold might perhaps be explained by the whole being formed by an ice-sheet coming from the north-east, which carried Scandinavian rocks over the North German plain, and some as far as the English coast.

The Author replied to Mr. Topley that brown clays were found on both sides of the Chalk Wold, some of those on the west of the wold being identical in character with the Hessle Clay, and such as could not have been derived from the blue chalky clay by any process of weathering. Some of what has been called Hessle Clay may have been so derived from the Purple Clay.



J. J. H. Teall del.

J. W. Watson del et lith.

DOLERITE AND HORNBLENDE SCHIST

Watson Bros & Douglas lith Birmingham

17. *The* METAMORPHOSIS *of* DOLERITE *into* HORNBLENDE-SCHIST. By J. J. H. TEALL, Esq., F.G.S. (Read January 14, 1885.)

[PLATE II.]

THE object of this communication is to describe the gradual change from dolerite to hornblende-schist as it may be observed in two more or less parallel dykes which occur in the Archæan gneiss of the north-west of Scotland, near the village of Scourie in Sutherlandshire.

The northern promontory of Scourie Bay is named on the Ordnance map Creag a'Mhail. Near this point two dykes of basic igneous rock may be seen. The one to the south is about 30 yards wide; it has been more affected by denudation than the surrounding gneiss, and its course is thus marked by a depression which is occupied by the sea at high tide. A short distance to the north of the actual promontory is another dyke, about 20 or 30 feet wide, of similar character, which terminates westward in a vertical cliff. This may be traced in a south-easterly direction down to a small beach where the southern dyke is again seen, and from this point the two dykes may be followed, running parallel to each other towards the south-east, for a distance of a quarter of a mile or more. The prevalent strike of the gneissic banding in this district is E.N.E. and W.S.W., with a moderate dip to N.N.W. The dykes therefore cut across the strike and cannot possibly be regarded as bands in the gneiss.

On the opposite shores of Scourie Lake (Loch a' Bhaid Daraich) and close by the side of the road to Laxford Bridge (three quarters of a mile from the Scourie Hotel), the dykes again make their appearance. Prof. Blake first recognized the northern dyke at this spot on the occasion of our joint excursion to the north-west of Scotland in the summer of 1883. This dyke is here the wider of the two and forms a portion of the conspicuous hill which overlooks the lake. The southern dyke produces a marked gap to the south of the hill. The distance between the two dykes is only a few yards. The junction-planes of gneiss and dyke are nearly vertical, and the fact that they cut across the gneissic banding is most clearly shown.

From this point the dykes may be traced to the south-east for more than a mile. What becomes of them ultimately in this direction I do not know; but, so far as I followed them, they keep very closely to the same straight line and preserve their lithological characters (subject to such exceptional variations as will presently be described) with as much persistence as the dykes in the Carboniferous region of the north of England.

The rock forming these dykes occurs in two strongly marked varieties. The one is a moderately coarse-grained, crystalline,

granular rock of true igneous character *; the other a typical hornblende-schist. These two varieties shade into each other by the most imperceptible gradations. The distribution of the two varieties throughout the dykes is somewhat irregular. In many places and for considerable distances no trace of foliation can be detected, in others the whole mass of the dyke is foliated. The prevalent strike of the foliation in the district lying to the south-east of the hill overlooking the lake is nearly at right angles to the course of the dykes, and therefore parallel with the strike of the prevalent gneissic banding.

In some places the distribution of the foliated and non-foliated varieties is extremely irregular and quite independent of the course of the dyke; at others it exhibits a marked tendency to bend round so as to become parallel with the margins. This latter feature is especially developed at certain points where the gneiss and dyke become very intimately blended along the junction-planes, owing to the extension of tongues and flame-like processes of the dyke into the gneiss. At these points there is often perfect parallelism between the foliation of the gneiss and dyke, and it is possible to obtain hand specimens in which the rock of the dyke is represented by a band of hornblende-schist in the gneiss.

The jointing of the dyke is often very irregular, the planes appearing bent and twisted. This may be well seen at the small beach on the north side of Scourie Bay. Veins of quartz traverse the dyke in certain places, and at the small beach above referred to a vein of nearly pure felspar occurs. The surface of the felspar is weathered, but the main mass is very fresh. One cleavage is strongly marked, so that the mineral has a platy structure. Twin-striation is not, as a rule, recognizable; but Dr. Trechmann tells me that the principal cleavage is parallel to the brachypinacoid, and that would account for it. In one case I have observed twin-striation on a cleavage-face. To determine the specific gravity, seven small grains of the pure felspar substance were selected. In a Sonstadt solution having a sp. gr. of 2·638, two rose, one remained suspended, and four sank. In a solution the sp. gr. of which was 2·644, three rose, one remained suspended, and three sank; and in one, the sp. gr. of which was 2·654, three rose, and four remained suspended. The specific-gravity determinations therefore indicate andesine, and this is confirmed by the following analysis:—

* A dyke having the same strike and composed of a rock precisely similar to the one here referred to occurs on the N.E. shore of Loch Glen Coul. The water of the lake is in contact with the dyke for some distance. If the Scourie dykes were continued towards the S.E. in the same straight line they would pass a mile or two to the N.E. of the Glen-Coul dyke.

Andesine from Scourie Dyke *.

SiO_2	58·16
Al_2O_3	26·66
CaO	5·79
MgO	·65
Na_2O	6·99
K_2O	1·76
	100·01

The recent work of Descloiseaux † appears to have placed beyond doubt the independent existence of andesine. I now proceed to describe in detail the lithological characters of the principal varieties of rock.

Dolerite (*Diabase* ?). The least modified specimens are dark in colour and coarsely crystalline in texture. The augite grains and crystals frequently measure 1 mm. across, and the felspars 2 mm. × ·5 mm. Three specific-gravity determinations made on samples from different localities gave 3·106, 3·105, and 3·086. A bulk-analysis of the rock yielded the following result ‡ :—

SiO_2	47·45
TiO_2	1·47
Al_2O_3	14·83
Fe_2O_3	2·47
FeO	14·71
CaO	8·87
MgO	5·00
K_2O	·99
Na_2O	2·97
H_2O	1·00
CO_2	·36
	100·12

Under the microscope the rock is seen to consist of felspar, augite, titaniferous magnetic iron-ore, apatite, and some secondary products, including hornblende, chloritic minerals, quartz, and pyrites. The secondary minerals, however, occur only in very small quantity.

The felspar is usually present in lath-shaped sections of the type common in dolerites and diabases; but occasionally plates of felspar having a polysynthetic structure may be recognized, in which the individual portions are not bounded by any definite crystalline faces.

In the freshest slides the felspar-sections are often perfectly limpid, but as a rule they show traces of alteration, and in some cases

* Dr. Heddle gives four analyses of andesine in his paper on the Scotch felspars, Trans. Roy. Soc. Edin. xxviii. p. 246.

† Bull. Soc. Min. France, July 1884.

‡ P_2O_5 and S (in FeS_2) were not estimated. The P_2O_5 is therefore reckoned with Al_2O_3. The water was determined absolutely. There was a slight gain on ignition, showing that the oxygen taken up by the FeO was more than sufficient to counterbalance the loss due to expulsion of water &c.

have lost all individual action on polarized light. In the sections which are more or less turbid, the cracks are frequently stained with limonitic decomposition-products. Various modes of twinning may be observed. Simple crystals and binary twins are common; so also are sections showing very fine multiple twinning and the cross hatching attributed to simultaneous twinning on the albite and pericline types.

Optical anomalies due to strain are frequently recognizable. The extinction-shadows sweep over the sections as the stage is rotated under crossed nicols. The lines separating adjacent twin lamellæ are frequently curved; and sometimes, where the limit of elasticity has been exceeded, a crystal is seen to have been fractured. The twin lamellæ often show a great want of persistence in one and the same crystal; and sometimes they appear to be related to the fractures in such a way as to suggest that they may be, in part, of secondary origin *.

The pyroxene occurs in irregular grains, imperfect crystals, and plates, which may be either simple or polysynthetic. The lath-shaped felspars sometimes penetrate the pyroxene, and the rock then possesses the ophitic structure of MM. Lévy and Fouqué.

In the very thin sections examined the pyroxene is either colourless, or very pale chocolate-brown. The characteristic cleavages, polarization-tints, mode of twinning, and extinction-angles prove very clearly that the mineral is a typical monoclinic pyroxene.

The bulk-analysis of the rock makes it in the highest degree probable that the mineral is extremely rich in ferrous † oxide.

The titaniferous magnetic iron-ore occurs in irregular plates, and sometimes in what appear to be skeleton rhombohedra. Apatite is present in the usual colourless hexagonal prisms. Quartz and chloritic minerals may be recognized, both doubtless of secondary origin, and occasionally the pyroxene is seen passing over into green hornblende, the characteristic mineral of the rock now to be described.

Hornblende-schist. The rock in its typical development is a fine lustrous schist. On a natural face at right angles to the schistosity the foliation is often strongly marked by alternating lenticular bands of dark and light colour, the former being rich in hornblende, the latter in quartz and felspar (see lower part of fig. 1). As a rule, the bands do not show crumpling or puckering; but in one case this was observed. The individual constituents of the schist are much smaller than those of the dolerite. The average size of the sections of hornblende exposed in a slide cut at right angles to the schistosity, and parallel to the direction in which the long axes of the hornblende grains are usually arranged, is somewhere about ·4 mm. × ·15 mm.

The specific gravities of two specimens of the schist were found to be 3·111 and 3·122. There is therefore a very close agreement

* Lehmann, 'Die Entstehung der altkrystallinischen Schiefergesteine,' p. 196, plate c. fig. 1.

† See "Analysis of Whin Sill pyroxene," Q. J. G. S. 1884, p. 648.

between the dolerite and the hornblende-schist, so far as specific gravity is concerned. A bulk-analysis of the schist also shows a close agreement with that of the dolerite:—

SiO_2	49·78
TiO_2	2·22
Al_2O_3	13·13
Fe_2O_3	4·35
FeO	11·71
MnO	·27
CaO	8·92
MgO	5·40
K_2O	1·05
Na_2O	2·39
CO_2	·10
H_2O	1·14
	100·46

The slightly greater percentage of silica in the schist is exactly what the microscopic analysis would lead one to expect. It would be interesting to know whether this is a constant feature, and, if so, whether the silica has been introduced from without, or whether bases have been removed. The isolation and separate analysis of the individual constituents of the two rocks would probably lead to interesting results. The fact that the schist contains more iron in the ferric state, suggests that an oxidation of a portion of the iron occurs in the change from augite to hornblende. This would effect the liberation of a certain amount of silica; and it is interesting to note that in certain granular varieties of the rock, in which hornblende occurs to the exclusion of augite, detached grains of a clear mineral resembling quartz may frequently be seen scattered through a plate of hornblende having definite optical properties.

The constituents of the rock are hornblende, quartz, felspar, or minerals resulting from the modification of felspar, titaniferous magnetic iron-ore, sphene, and apatite. The rock is to all intents and purposes holo-crystalline and possesess the true micro-structure of a schist.

The hornblende occurs in irregular grains, which possess definite optical properties, but are without external crystalline faces. They are usually of unequal dimensions in the different directions, and the corresponding axes of the different grains lie roughly, but not rigidly, parallel to each other in the rock. The longest diameter of a grain usually corresponds approximately to the vertical axis of the crystal, and lies in the plane of schistosity; the mean diameter corresponds with the orthodiagonal, and also lies roughly in the plane of schistosity; the shortest diameter corresponds with the clinodiagonal, and lies at right angles to the plane of schistosity. The general tendency to this mode of arrangement is admirably brought out when a section at right angles to the plane of schistosity and parallel to the direction of arrangement of the longest diameters is compared with one parallel to the plane of schistosity. On rotating the

former section over the polarizer, the vast majority of the grains are seen to change from a rich deep green to a very pale greenish yellow. The green tint appears when the direction of schistosity lies approximately parallel to the plane of vibration, and is due to the fact that the least axes of elasticity are only slightly inclined to the long diameters of the grains. The pale greenish-yellow appears in the opposite position, and is due to vibration parallel to the least axes of elasticity in the different grains. On rotating the section parallel to the schistosity in a similar manner, the grains change, as a rule, from deep rich green to dark yellowish green, the former tint being due to vibrations parallel to the least, and the latter to vibrations parallel to the mean axis. It must be distinctly understood that the above orientation of the grains in the rock, though strongly marked, is not by any means rigidly followed.

In some non-foliated varieties of the rock of these dykes, plates of hornblende of considerable size with perfectly characteristic cleavages occur; and by experimenting on these it is possible to make out the characteristic pleochroism of the mineral. If we take α, β, and γ* to represent the greatest, mean, and least axes of elasticity respectively, then it may be defined as follows :—

α = Very pale greenish-yellow.
β = Dark yellowish-green.
γ = Rich deep green.

The absorption for rays vibrating parallel to β and γ is considerable, that for rays parallel to α is very slight.

Next in importance to the hornblende are the pellucid grains of quartz and felspar. These do not show a trace of external form. The majority of them are simple, but a few show signs of twin-striation. At first I thought these grains were almost entirely composed of quartz; but the chemical analysis shows such a close agreement between the schist and the dolerite that I can hardly regard this view as probable. Some facts will be mentioned later on which throw light on the molecular changes observed in the felspar-substance; but at present I must confess that I feel considerable doubt as to the possibility of separating the quartz from the felspar in this rock by microscopic examination.

The titaniferous iron-ore is sometimes seen in the form of long strips which lie in the plane of schistosity, and at other times it is present as small grains which occur as inclusions in the other crystalline constituents. It is sometimes partially surrounded by grains of sphene. Broken prisms of apatite may frequently be recognized. The only other constituents of any note are a few turbid grains of what is in all probability felspar. The rock is therefore a typical hornblende-schist.

The two extreme modifications of the rock forming these dykes have now been described at sufficient length. From a consideration of all the facts of the case, I have been led to the conclusion that

* The form of the ellipsoid is assumed to be that usually observed in hornblende.

the hornblende-schist has been produced by metamorphic change in the dolerite after consolidation, and it will conduce to clearness if the remaining facts are described from this point of view. If my conclusions should turn out to be erroneous, the phraseology adopted would require modification, but the facts would of course remain unaltered.

In considering the question of metamorphism as it affects the Scourie dyke, two points have to be attended to:—(1) the molecular rearrangement, (2) the development of foliation. An examination of a series of sections cut from different specimens of the non-foliated rock shows that a gradual transition occurs from the typical dolerite with lath-shaped felspar sections to a crystalline granular aggregate of hornblende, felspar, quartz, and titaniferous magnetic iron-ore, in which all trace of the true microstructure of the dolerite has been lost. This shows that the molecular rearrangement may take place without the development of foliation. The change from augite to hornblende has been so frequently described that it is quite unnecessary to enter into details on the present occasion. All stages of the transition may be observed in the sections taken from different specimens of these rocks, but not in sections taken from any one specimen. Some show the augite with marginal hornblende; others show the hornblende with a distinct nucleus of augite; and others show the hornblende containing indistinct patches and fibres of augite. The final stage is of course one in which no trace of the original augite exists. The appearance of quartz in connexion with this change has been already referred to.

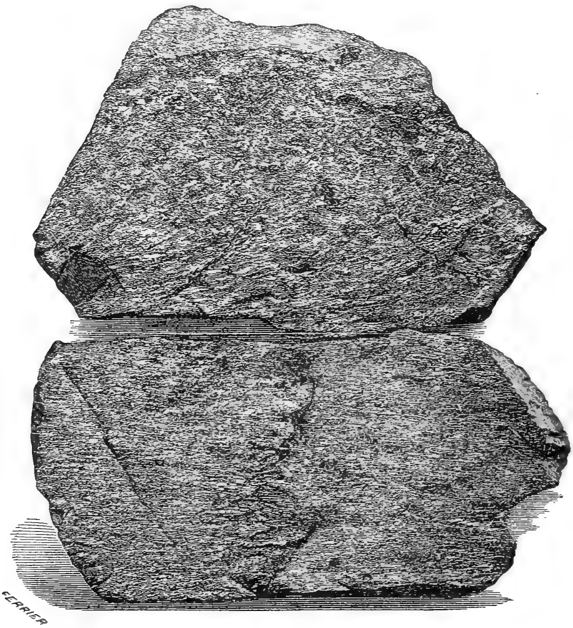
The changes in the felspar substance are equally remarkable, though not so well understood. The original felspars, with their characteristic twin-striation, may be traced into an aggregate of distinct grains frequently without twinning, and having independent optical relations. The general structure of these aggregates frequently reminds one of saussurite.

Sometimes the felspar substance is turbid, but in many sections it is perfectly clear and limpid, and difficult to distinguish from the quartz, which also occurs in these sections. I regret that I am unable to give a more complete account of the modifications which the felspars undergo. That they suffer a complete molecular rearrangement is the only point which seems tolerably clear. The modification of the titaniferous magnetic iron-ore is partly mechanical and partly molecular; that of the apatite is, I think, simply mechanical*.

* The relations of the individual crystals and crystalline grains which form the constituents of rocks, to the deforming forces brought into operation in connexion with orogenetic movements, is a subject that will require much careful investigation. One or two facts of importance appear to be established. Under certain circumstances, as Prof. Bonney, Dr. Lehmann, and others have shown, the individual minerals become crushed, and a rock to which the term clastic is strictly applicable may be produced without the agency of denudation. Under other circumstances the deformation appears to be accompanied by molecular rearrangement without anything analogous to crush. Thus Heim

With regard to the development of foliation the evidence is very satisfactory. The transition from a crystalline granular rock to a perfectly typical schist may occur in the space of an inch. The specimen figured (fig. 1) was accidentally fractured, and a little of

Fig. 1.—*Block showing Passage from Granular to Foliated Structure.* (Three fourths natural size.)



(Mechanismus der Gebirgsbildung, Band ii. p. 55) calls attention to the fact that in a cleaved crystalline limestone belonging to the Hochgebirgskalk, the individual calcite grains are of unequal dimensions in the different directions, and have their longest diameters lying parallel to each other in the plane of cleavage, although in the uncleaved rock the crystalline grains are of nearly equal dimensions in the different directions. He suggests that this is due to the plastic deformation of the individual grains of calcite. Lehmann (Die Entstehung der altkrystallinischen Schiefergesteine, p. 197) objects to this view, and calls attention to the evidences of fracture and crush occurring in the rocks investigated by him. The fact established by Heim requires an explanation, however, and the most obvious one is the assumption that a molecular rearrangement occurs in the calcite under the mechanical conditions which determine the cleavage. The following important questions remain to be solved:—

Under what conditions is the deformation of rocks accompanied by a crushing of the individual constituents? Under what conditions is it accompanied by entire molecular rearrangement? And lastly, Under what conditions do these two more or less opposite phases of metamorphism occur at one and the same time?

In the north-west of Scotland there are schists that have been formed by

the intervening material lost: but the two portions are represented in their natural position, and the zone of transition is fortunately preserved in the upper one. A large section prepared through the zone of transition shows in a very perfect manner its gradual character.

In what way was the foliation produced? The only answer that seems possible is, that it was caused by movement when the mass was in a plastic state; but plasticity may arise in two ways. Under moderate pressures it can only occur when the material is in the fluid condition, that is, when the cohesion is slight; but under very high pressures it may be produced in bodies which are solid under ordinary circumstances *. This notion of the plasticity of solids is, of course, one of immense significance in relation to rock-deformation, and is doubtless destined to play a most important part in all questions relating to the origin of the crystalline schists. The phenomena of the Scourie dykes appear to me to show that the plasticity which has led to the development of foliation, is that due to high pressure at ordinary temperatures, rather than to high temperatures at ordinary pressures.

The optical anomalies due to strain, the bending of the twin lamellæ, and the actual fracture of the felspar crystals of the dolerite, are best explained on the assumption that the rock has been affected by pressure after consolidation, and the same assumption explains the curved and confused arrangement of the joint-planes which is occasionally observed. Then the fact that the planes of foliation frequently cut across the dyke and run parallel with the prevalent strike of the gneissic banding, is difficult to account for on the view that the foliation was produced by movement during the final stages of consolidation, though easy to explain on the alternative hypothesis. The curious interfelting of gneiss and dyke at the junctions in certain places also appears to indicate movement posterior to consolidation†.

Mechanical deformation accompanied by molecular rearrangements has profoundly affected the gneiss itself; and I have little doubt that some of this has taken place since the intrusion of the dyke.

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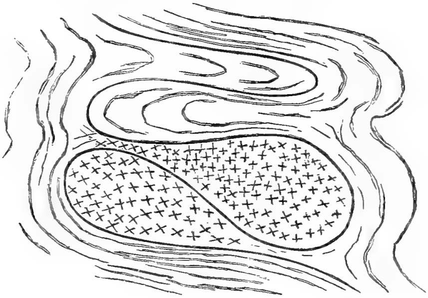
mechanical action alone, others that have been formed by mechanical action supplemented by a certain amount of molecular rearrangement, and others, again, like the hornblende-schist of the Scourie dyke, in which a complete, or nearly complete, molecular rearrangement has taken place. The data for the solution of the above problems are therefore in all probability to be found in this region.

* Tresca, "Flow of Solids," Proc. Inst. Mech. Eng. 1878, p. 301.

† It is interesting to note that if this process of interfelting were carried on to a much greater extent, it would lead to the disappearance of the dyke as such. The only evidence that would then remain to attest the former existence of the dyke would be the presence of bands of hornblende-schist in the gneiss. We know nothing as to the age of the dyke except that it is later than the so-called Archæan gneiss. It is somewhat interesting to contemplate the possibility of a later dyke of unknown age becoming part and parcel of Archæan gneiss; and the reflection may serve to suggest that our gneisses and schists may be of very complex origin, and may contain, as Prof. Lapworth holds, elements derived from formations of very different geological age.

One fold occurring not far from the dyke is figured below (fig. 2). The parts marked with crosses are lumps of hornblende-rock.

Fig. 2.—*Fold in Hebridean Gneiss,* 3 *or* 4 *feet across.*



Another argument tending to show that the foliation has been developed by mechanical action subsequent to consolidation may be founded on the fact that the parallel structure does not occur in the rock in which the original augite and felspar may be recognized. The hornblende occurs alone in the foliated portion.

The relations of augite to hornblende are of great interest in connexion with the origin of the crystalline schists, and they have recently been discussed by the American lithologists, Prof. R. D. Irving * and Mr. G. H. Williams †, at considerable length. Mr. Williams points out that augite appears to be the stable form at high temperatures, hornblende at low temperatures, so that any condition tending to facilitate molecular readjustment at ordinary temperatures must necessarily tend to facilitate the change from augite to hornblende. The enormous pressures brought into operation in the process of mountain-making may, as Mr. Williams states, not unreasonably be supposed to supply such conditions. The relation of crystals to their environment is one which lithologists have most carefully to consider. A crystal is doubtless in stable equilibrium, so far as the molecular forces are concerned, when subject to the conditions under which it is formed. Under other conditions it may be in unstable equilibrium, and ready therefore to undergo molecular readjustment the moment such readjustment becomes possible.

We conclude, then, (1) that the hornblende-schist of the Scourie dykes has been developed from a dolerite by causes operating after the consolidation of the dolerite, and that the metamorphosis has been accompanied by a molecular rearrangement of the augite and felspar; and (2) that the molecular rearrangement has, in certain cases, taken place without the development of foliation.

* Amer. Journ. Sci. ser. 3, vol. xxvi. p. 27 (1883); *ibid.* vol. xxvii. p. 130 (1884).

† Amer. Journ. Sci. ser. 3, vol. xxviii. p. 259 (1884).

To give anything like a critical account of the previous work bearing on the subject would increase the length of this paper to an extent that seems scarcely desirable. I may mention, however, a few facts which show that the point here advanced is by no means new. Dr. Geikie, in his review of Dr. Lehmann's work, in 'Nature,' mentions that Prof. Jukes long ago suggested that many areas of hornblende-rocks may be due to the metamorphosis of basic lavas and tuffs. Mr. Darwin in his 'Geological Observations,' 2nd edit. p. 432, calls attention to the gradual passage from hornblende-slate to greenstone; but he regards the latter rock as representing the extreme of metamorphism. Mr. Allport, in his valuable paper "On the Metamorphic Rocks surrounding the Land's-End mass of Granite" (Q. J. G. S. vol. xxxii. p. 422), refers to certain greenstones which "might almost be described as hornblende-schists," and in his summary expresses the opinion that "hornblende-schists may be metamorphosed igneous rocks, some being derived from dolerites or gabbros, while others are very probably foliated diorites."

"Schistose greenstones" are described by Mr. J. A. Phillips in his two papers "On the so-called Greenstones of Cornwall" (Q. J. G. S. vol. xxxii. p. 155 and vol. xxxiv. p. 471). Prof. Bonney, in a paper on "The Hornblendic and other Schists of the Lizard District" (Q.J.G.S. vol. xxxix. p. 14), refers to the transition from hornblende-schists to a rock resembling diorite.

Dr. Lehmann, in his work 'Die Entstehung der altkrystallinischen Schiefergesteine,' describes the passage of gabbro into schistose amphibolite. M. Renard, M. von Lasaulx, and others hold that the amphibolite schists of the Ardennes have been produced by the mechanical metamorphosis of diorite. Adolf Schenck describes schistose diabase in a paper on "Die Diabase des oberen Ruhrthals," Inaugural Dissertation, Bonn, 1884.

This account of previous works bearing on the subject is very incomplete, but it is sufficient to show that the conclusions suggested by an examination of the Scourie dykes have been more or less anticipated by many previous writers.

In concluding this paper, I should like to take the opportunity of acknowledging my indebtedness to Prof. Lapworth. In the summer of 1883 he very kindly conducted Prof. Blake and myself over the Erribol area, and explained to us the very complicated stratigraphy of that interesting region. He called our attention to the secondary structures developed in the rocks by mechanical action, and instructed us where to collect specimens that would best serve for the purpose of microscopic examination. At the time we were on the ground I could not follow him at all points, because the subject was new to me as regards both the stratigraphy and the petrography. Indeed it was not until I had examined the rocks collected under his supervision, as well as others obtained by myself in other regions of the north-west of Scotland, by the aid of the microscope, and had read the work of Dr. Lehmann, published shortly after, that I fully realized the significance of many points that Prof. Lapworth had insisted upon. Although Prof. Lapworth has not seen the

Scourie dykes, I feel that it would not be right to allow this paper to pass without pointing out that the ideas expressed in it have been to a very great extent suggested by the lessons he taught me in the Durness-Erribol area during the summer of 1883.

EXPLANATION OF PLATE II.

Fig. 1. Dolerite (diabase) section showing lath-shaped felspars, crystalline plates of augite, titaniferous magnetic iron-ore, secondary hornblende, and green decomposition-products. Magnified 24 diameters.

2. Hornblende-schist viewed with polarizer only. Plane of vibration at right angles to schistosity. Hornblende, colourless crystalline grains (quartz and modified felspar), and titaniferous iron-ore partially surrounded with sphene. On rotating stage through 90°, all the yellowish-green grains change simultaneously to deep green. Magnified 50 diameters. The hornblende is more abundant in the portion of schist here represented than is usually the case.

Discussion.

The President pointed out that while others had suggested the relations in certain cases between igneous and metamorphic rocks, to the author belonged the merit of having demonstrated this in a particular instance. He agreed with him that the schistosity of the rock of the dyke could not have been produced during the cooling of the mass. He had always thought that some of the hornblende-schist of the Lizard might similarly have been derived from basic igneous masses; but when working there he had failed to obtain any proof of it.

Mr. Bauerman remarked on dykes in the older Archæan rocks of South America, which sometimes run along planes of foliation and at others cut across them. He thought that in such cases the dykes were probably not very different in age from the gneiss which they traverse.

Prof. Seeley said that the interest of Mr. Teall's work was in the direct conversion of a volcanic texture into a schistose texture; but though the fact was new, it did not need any new views in metamorphism to explain it. We could only conceive of the change taking place after the dyke had cooled and cracked, because the rock could not otherwise have offered the resistance under which the crystals would extend themselves at right angles to pressure in the foliated part. He thought that the change had been an extremely slow one, due to the temperature of the water in the cracked rock being raised by pressure, so that it had slowly dissolved the material of the dyke, which had as slowly recrystallized in a schistose form. Mr. Teall's account was conclusive; but such origins for hornblende-schist are necessarily local.

Dr. Hicks thought that the case cited in this paper, where one crystalline rock was changed into another and into closely allied minerals, probably by infiltration along minute fissures, lent no

support to the extreme views held by some concerning the metamorphism of sedimentary rocks.

Prof. BLAKE asked how it was that one part of the dyke was changed while the other part was not. He objected to the view that because the change might take place in a range of a few inches, therefore great masses of rock could be changed in the same way.

Mr. HUDLESTON remarked on the difference between the hornblende-schist of the dyke, consisting largely of hornblende and an altered felspar, and the common hornblende-schist, which consists chiefly of hornblende and quartz.

Mr. KILGOUR called attention to the fact that by pressure a similar fibrous structure is produced in cast-iron.

The AUTHOR, in reply, pointed out that while the gneiss of the country showed signs of great disturbance, the dyke maintained its direction with a considerable amount of regularity. It seemed evident then that the disturbances to which the gneiss had been subjected must in the main have been produced before the intrusion of the dyke. He had not argued that all hornblende-schists were metamorphosed dolerites, but only that a particular hornblende-schist been produced in this way. Why movement and metamorphism had occurred at certain points and not at others he could not explain. The typical schist of the dyke was composed almost entirely of hornblende and a mineral or minerals occurring as colourless crystalline grains. Turbid felspar was rare, and, in the most perfect schist, almost if not entirely absent. The colourless grains he originally regarded as quartz, but he now felt considerable doubt as to their precise character. In every respect, so far as his experience enabled him to judge, the schist appeared to resemble the typical hornblende-schists of the so-called Archæan rocks.

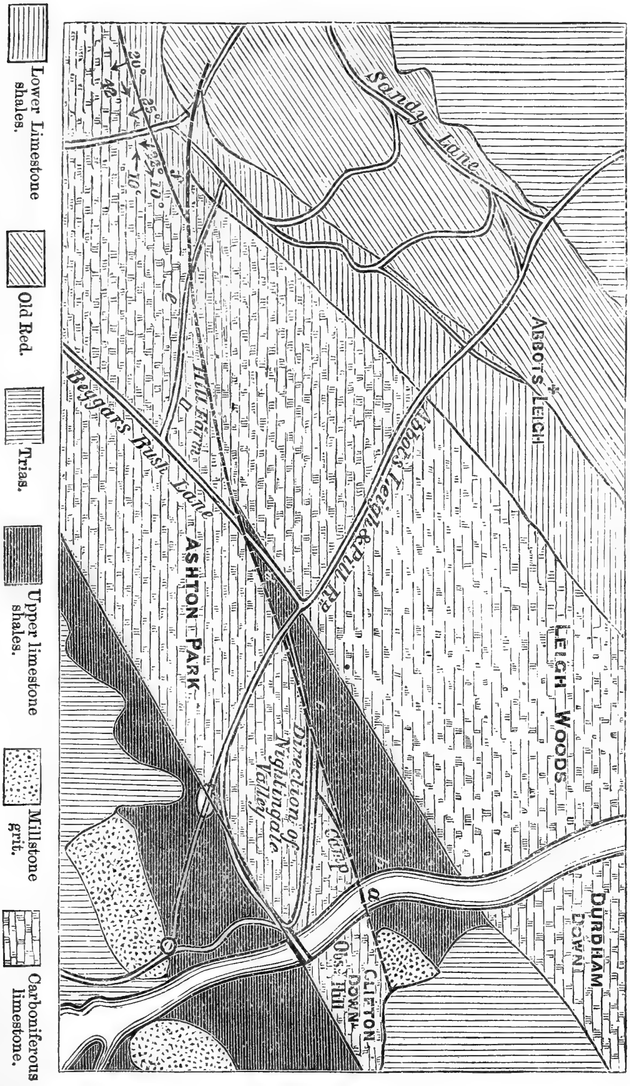
18. *On the* S.W. EXTENSION *of the* CLIFTON FAULT. By PROF. C. LLOYD MORGAN, F.G.S., Assoc. R.S.M. (Read December 17, 1884.)

ON the right bank of the Avon, somewhat below the Suspension Bridge and a little beyond the Clifton station of the Bristol Port railway, the Clifton fault cuts across the strata somewhat obliquely. On the southern side of the fault is massive Mountain Limestone, forming the bold bluff of the Observatory Hill. On the northern side are much contorted red grit and limestone shales (see Map, p. 147).

Viewed from the opposite side of the river, the right bank, from the Suspension Bridge for half a mile northwards, shows the following features. The eastern tower of the Suspension Bridge is built on a solid mass of limestone, the western face of which fronts the river as an almost perpendicular wall of rock. At right angles to this, and parallel with the bridge-road, there is a second face due probably to a joint plane, or a minor dislocation of the strata parallel with that caused by the Clifton fault. This vertical face forms the southern boundary of a little recess in the rocks, in which lies the Clifton station. On the northern side of the station rises the somewhat dislocated mass of limestone which forms Observatory Hill, and which, on its southern side, abuts against Millstone Grit and Upper Limestone Shales brought down by the Clifton fault. The whole appearance of the side of the ravine now changes, and in place of vertical limestone cliffs there is a wooded slope. Close to the river, however, the rocks are well seen in section, and show bands of hard grit characteristic of the Upper Limestone Shales. These bands, passing under the Avon at the point marked *a* on the map, have hitherto caused a shallowing of the river at this point. Blasting operations are at present in progress by which this obstruction will be removed. Some 370 paces from the fault, solid limestone rises from the river-side (at *c*), but is, a little further north, cut into by a wooded notch (*b*) in which runs the path, known as the New Zigzag, which joins the road near Proctor's Fountain. This notch starts from the point of junction, at the surface of the downs, of the solid Mountain Limestone and the Upper Limestone Shales, which are, however, here unconformably overlain by the dolomitic conglomerate of the Trias.

The throw of the fault on this Gloucestershire bank I estimate at about 1150 feet vertically, which is some 350 feet greater than that given by Buckland and Conybeare (Trans. Geol. Soc. 2nd series, vol. i. p. 241), and by W. Stoddart (Proceedings of the Bristol Naturalists' Society, new series, vol. i. p. 328). On the Somersetshire bank I make the throw 50 feet less. This difference may be due, in part at least, to the dying-out of the fault in that direction. Taking as a datum-point the intersection of the line of fault and that of high water on the Gloucestershire side, the rocks which have been relatively shifted downwards are Mountain Limestone, about 710 feet, and Upper Limestone Shales about 440 feet. If we take

Sketch Map to illustrate the Western Extension of the Clifton Fault.
(Scale about $2\frac{1}{2}$ in. to 1 mile.)



a–f. Localities specially referred to in the text.

Mr. Stoddart's estimate (Geol. Mag. vol. ii. p. 83) of the thickness of the Upper Limestone Shales at 600 feet, which I think is a fair one, there will be 160 feet or so of these beds above high-water mark, above which the Millstone Grit will be brought down. This accords very well with the facts, that contorted grits and shales are seen from the new road some 50 or 60 feet above high-water mark, and that above this little but grit is to be found. It must be remembered, however, that the beds in the immediate vicinity of the fault on the down-throw side are exceedingly contorted.

A curious effect of the general squeeze by which the rocks here are literally "in one red burial blent," is well shown in the immediate neighbourhood of the line of fault on the Gloucestershire side of the river. Here, over a face of limestone dipping 18° N., has been thrust a semicircular mass of rock with an external layer of grit, then a band of limestone, and internally a core of grit.

Further eastward on this same Gloucestershire, or Clifton, side of the Avon, the effects of the fault on the physical features of the country are well marked, causing the well-defined depression in which lie Triassic beds between the Clifton Downs (with its tongue-shaped mass of limestone stretching westward from the Suspension Bridge) on the south, and the northward-trending limestone mass of Durdham Downs on the north. (See map.)

Passing now to the opposite, or Somersetshire side, we find the following features, as seen from such a standpoint as the Observatory Hill. A little to the north of the Suspension Bridge is the deep indentation of Nightingale Valley, the southern side of which is here precipitous, and answers to the vertical face which forms the southern boundary of the station-recess on the Gloucestershire side of the river. The northern side of the valley is less precipitous, forming, in fact, more or less of a dip slope of limestone. A hundred and fifty yards or so further north is another precipitous face of limestone, that caused by the fault. After this, as we pass northwards, there is, on this side of the river as on the Clifton side, a wooded slope. The solid limestone rises from the river-side at a distance of some 240 paces from the faulted limestone face.

Owing to the fact that the fault cuts across the strata obliquely, lower beds of the Mountain Limestone are intersected on this side of the Avon than were cut on the Clifton side. Hence the rocks relatively shifted downwards at the point of intersection of the line of fault and the line of high water here are Mountain Limestone, about 780 feet, and Upper Limestone Shales about 330 feet, making a relative displacement of 1100 feet. Remembering that the Upper Limestone Shales are some 600 feet in total thickness, this leaves 270 feet of these rocks, which would thus just extend to the top of the cliff. Under these circumstances we should not expect to find Millstone Grit faulted down on this side of the river. Nor have I on careful search been able to discover any beds of this rock. At the point marked *b* on the map, however, I have found well-defined bands of grit interstratified with limestone, showing that we here have beds of the Upper Limestone Shale.

In Messrs. Buckland and Conybeare's paper on the S.W. Coal-district (Trans. Geol. Soc. 2nd series, vol. i. p. 242), attention is drawn to the fact, "that the fault may be traced up the gully which bounds the northernmost of the two Roman camps in Leigh Wood." Beyond this suggestive observation I am not aware of any published account of attempts to trace the further south-western extension of the fault. But since the Upper Limestone Shales faulted down are softer than the solid limestone, we might very probably, so it seemed to me, find a *line of depression* marking the line of fault and running south-westward from this gully. Such a line of depression actually exists; and I have ventured to mark it in the accompanying map as Upper Limestone Shales. It runs from the neighbourhood of Hill Farm across Beggars' Bush Lane, through the northern corner of the Ashton Park estate, across the Abbots Leigh road, in which the depression is well marked, and so to the head of Nightingale Valley, along which this natural line of drainage then passes, deserting the line of fault, which crosses Nightingale Valley about halfway up, and so passes to the gully mentioned by Messrs. Buckland and Conybeare. It is interesting to notice that the point where the fault crosses the Nightingale Valley is indicated by a well-marked change in the physical features. Up to that point the ascent is steep; beyond that point it is much more gradual. Up to that point the southern (left hand) side is precipitous, beyond that point it has a more gentle slope. Up to that point the valley is a deep notch, beyond that point it widens out. These changes result from the bringing in of the softer rock by the downthrow of the fault.

Another point is of interest. West of the point I have just alluded to, a triangular wedge of limestone is cut off by the line of fault and the line of the valley, which intersect at this point. (See map.) This triangular wedge of limestone formed too marked a natural feature to be missed by the Britons, who accordingly strengthened it by building a vallum along its faulted side; so that the line of this Stoke Leigh Camp (marked "camp" on the map), as suggested by Buckland and Conybeare, shows roughly the line of the fault.

I have before mentioned that beds of grit belonging to the Upper Limestone Shales are found on the Somersetshire bank at the point marked *b* on the map. Where the Upper Limestone Shales come in on the north side of Nightingale Valley, I have, however, not succeeded in finding any definite bands of grit, though fragments of siliceous rock are abundant. Near the head of Nightingale Valley, at *c*, beds of clayey shale are exposed. And in the Ashton Park grounds, across the north corner of which I have been able, through the kindness and courtesy of Sir Greville Smyth, to follow the line of depression, there are some quarry-pits, at *d* (see map), in which white clayey bands are interstratified with bands of limestone. And, yet further to the south-west, in the fields that lie between Beggars' Bush Lane and Hill Farm House, there are many sandstone fragments mingled with stones of Mountain Limestone.

Before reaching Hill Farm the depression ceases or widens out somewhat indefinitely. This is what we should expect. For since the line of fault cuts across the strata obliquely, thus cutting lower and lower beds of the Mountain Limestone, and since the fault shows signs of dying out in this S.W. direction, a point must be reached when, instead of Upper Limestone Shales being faulted down against limestone, beds of Mountain Limestone are faulted down against lower beds of the same rock. And since it is only by the bringing in of the softer beds that the line of depression is produced, when these beds are no longer brought down to the present surface-level by the fault, the line of depression ceases.

I thought it worth while to calculate the distance at which the fault would cease to bring down Upper Limestone Shales to the present surface-level, on the supposition that it shows no tendency to die out in this direction. Supposing that the 600 feet of Upper Limestone Shales are just faulted down in the Leigh Woods, on the Somersetshire bank of the Avon, the breadth of surface covered by these beds, at a dip of $27\frac{1}{2}°$, would be about 1300 feet. The strike of the strata is 65° east of north, and the direction of the fault is 70° east of north. The fault therefore cuts the strata at an angle of 5°. At such an angle the 1300 feet of Upper Limestone Shales would gradually thin out, wedge fashion, as we pass westwards along the line of fault,—the point of the wedge, where the Upper Limestone Shales cease to come to surface, being about 4300 yards from the Avon. But Hill Farm, where the depression before alluded to ceases, is, according to Mr. Sanders' map, not more than 2200 yards from the Avon. The difference I believe to be evidence of the dying-out of the fault in this direction.

Beyond Hill Farm there is no means of tracing the fault. A quarry a little beyond the farm, at *e* (see map), shows no sign of shaly or sandy beds. But it is worthy of note that if we produce the line that is marked by the Upper-Limestone-Shales depression, in a west-south-west direction, until it cuts the junction of Mountain Limestone and Lower Limestone Shales, we find at this point a great confusion of dips. Within a couple of hundred yards or less we find 42° E.N.E., 25° S.S.E., 22° S., 10° W., 10° E.N.E. Still this represents but poorly the 1150 feet of throw on the Gloucestershire bank of the Avon. If the fault have not practically died out as such, we should expect, here in the neighbourbood of the junction of the softer Lower Limestone Shales and the harder Mountain Limestone, some more marked evidence of its existence. The only further evidence of this kind which I have found, and I do not wish to lay any great stress upon it, is this: that at a point a little to the north of the confused dips, in the midst of the line of depression that marks the Lower Limestone Shales, there is an island of Mountain Limestone, at *f* on the map. Owing to its existence Mr. Sanders, in his map, has carried his Mountain Limestone boundary-line outside this, so as to include it in the Mountain Limestone. But I would suggest, as possible, that this island of Mountain Limestone in the depression is the remnant of a wedge of this rock faulted into the Lower Lime-

stone Shales, there being also a corresponding wedging of the Lower Limestone Shales into the Mountain Limestone as indicated by the S-shaped boundary-line in the map. And I may mention that I have some evidence of the prolongation of the Mountain-Limestone wedge still further westward into the Old Red Sandstone.

In conclusion, I would draw attention to the fact that the marked north-east trend of the Mountain-Limestone uplands from the point of confused dips just alluded to, is undoubtedly, in part at least, caused by the Clifton fault; and to the further fact that the line of this fault is, roughly speaking, parallel with that of the great Clapton-in-Gordano fault. Messrs. Buckland and Conybeare suggested that "it is not improbable that the two may be connected;" but of this there is no direct evidence.

Discussion.

Dr. Evans thought the paper was one of great value; he asked if there were not proof of the existence of more than a single fault.

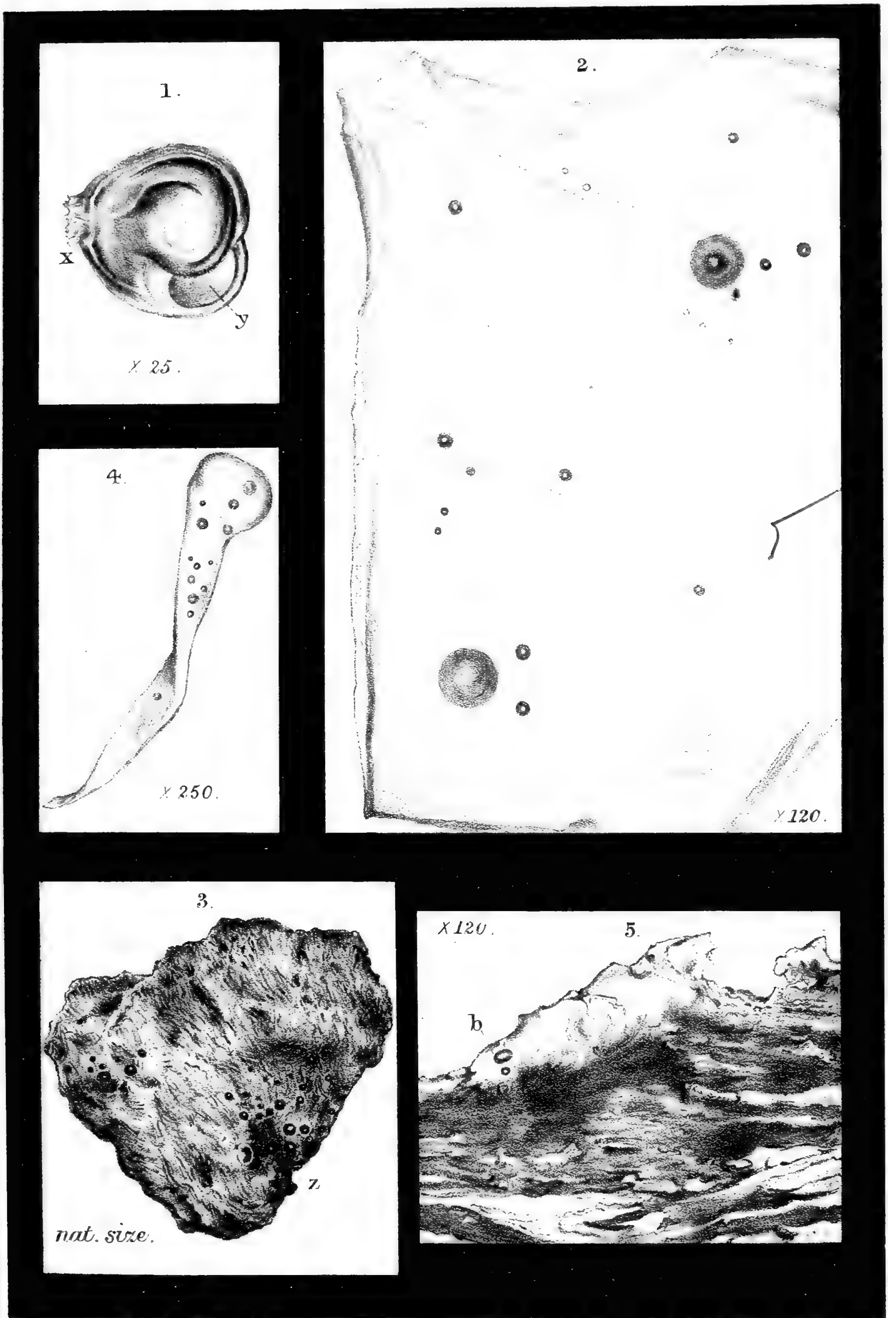
The Author said that at present he could find no proof of the existence of a fault in the line of the Avon gorge; the principal fault is nearly at right angles to the line of the river. In answer to the Chairman he said that to the east the fault was obscured to some extent by the overlying Trias.

19. *On* Fulgurite *from* Mont Blanc; *with a* Note *on the* Bouteillenstein, *or* Pseudo-chrysolite *of* Moldauthein, *in* Bohemia. By Frank Rutley, Esq., F.G.S. (Read January 25, 1885.)

[Plate III.]

An interesting paper by Mr. J. S. Diller, of the United-States Geological Survey, upon fulgurite from Mt. Thielson in Oregon, appeared in the 'American Journal of Science,' vol. xxviii. Oct. 1884, in which allusion was made to the effect of lightning upon hornblende-schist on the summit of Mont Blanc, as noted by De Saussure.

On reading this, I remembered that some years ago Mr. James Eccles gave me two or three small specimens showing evidence of fusion on their surfaces, which he at the time considered to be due to the action of lightning. They were collected by him on the summit of the Dom du Gouté from small peaks of rock rising out of the snow at a height of 14,000 feet above the sea-level. These peaks form part of the chain of Mont Blanc. The fragments are small and consist of hornblende gneiss; for they contain some felspar, and one of the specimens is traversed by coarse irregular foliations of felspar. Mr. Cuttell has made several attempts to prepare a section through this specimen with the thin fulgurite film adhering to it, but unfortunately failed, the fulgurite crumbling away in each trial. The cuts made through the specimen at various points show, however, that the fulgurite is quite superficial, no trace of fusion being visible below the original surface when the cut surfaces are examined with a lens. Indeed there appears to be no alteration of the rock from the electric flash, except on the actual surface itself, where a number of globules, sometimes in the form of attached spheres, sometimes in quite irregularly fused pellets and blotches of brownish-black and of white glass, have been formed. The latter is the frothy glass or enamel resulting from the fusion of felspar, while the dark glass is due to the fusion of hornblende. Upon one piece the surface is fretted and blistered over an area of about half a square inch. Some of the globules have minute holes from which gas has escaped; while others have been inflated into thin, spherical, or irregularly blistered bubbles (Pl. III. fig. 1). The dark glass is tough, some pressure being needed in order to detach small pieces from the broken bubbles. Fragments of these bubbles, when examined under the microscope with high powers, appear to be absolutely structureless and to contain nothing but a few small gas-bubbles (Pl. III. fig. 2). In this respect the glass corresponds precisely with the Mt. Thielson fulgurite described by Mr. Diller, for there is no trace of cystallization-products in either case. Pl. III. fig. 4 represents an elongated and twisted glass enclosure containing many gas-bubbles. It occurs in a fragment of the fulgurite. On the surface of one of the specimens three or four glass-bubbles, each about the eighth of an inch in diameter, adhere



Frank Rutley del. A. S. Foord lith.

Mintern Bros. imp.

FULGURITE ON HORNBLENDE-GNEISS, M^{T} BLANC.

to the rock quite close together, while from them a series of minute globules of glass appear to be scattered in a somewhat radiating manner, some of them being connected with the larger globules by a thin fretted trail on the surface of the rock, indicative of the sputtering of the fused material from the point struck by the lightning (Pl. III. fig. 3). The blow-holes of the glass vesicles from which the gas has escaped show an involution of the vesicle-wall around them, as though each hole had been formed by a wire pressed into the bubble while hot. This involution of the vesicles around the blow-holes is possibly due to fusion, cooling and contraction taking place with extraordinary rapidity. That the cooling of the glass was unusually quick is proved by its freedom from crystallites. Fulgurites, on this account, are probably the purest natural glasses ever formed.

The edge of a thin splinter of the rock taken from this specimen fused with intumesence, before the blow-pipe, to a dark glass similar to that of the fulgurite-globules.

The dark and the white glass globules do not, as a rule, appear to have mixed. They are often distinct, even when in contact, showing a clear line of demarcation between the two different kinds. Some instances may, however, be seen in which the dark shades off into the white glass. The fusion of both the hornblende and the felspar must have been so instantaneous, and the cooling so unusually rapid, that the fused surface of each crystal solidified almost exactly *in situ*, except where a sputtering of the molten matter was caused, either by the force of the electric shock or by sudden disengagement of gas from the fused material; for, in presence of such intense heat, the difference in the respective fusibilities of the hornblende and felspar cannot be taken into account.

On showing one of these fulgurites to Prof. Judd, he thought it might yet be possible to procure a microscopic section of the rock with some of the fulgurite adhering to it. It is to his kindness in making several preparations that I have been enabled to give the drawing of the edge of one of the sections showing the fulgurite, containing one or two gas-bubbles (*b* fig. 5, Pl. III.) attached to the rock. Unfortunately at this point the gneiss lying immediately beneath the fulgurite has some very opaque bands, which by reflected light appear white, not more so, however, than in many other parts of the section remote from the edge or original surface of the rock; and from this I think it may still be inferred that little or no alteration has been effected beneath the surface by the lightning. Some hornblende also underlies the fulgurite and still shows dichroism. The section at all events demonstrates that the vitrification has been purely superficial. The foliation just beneath the fulgurite is perfectly distinct. From a microscopic examination of those slides which were cut from a specimen containing coarse foliations of felspar it is seen that the rock is hornblendic gneiss, the constituents being chiefly hornblende, triclinic felspar, and quartz. The hornblende is of a deep reddish-brown colour by ordinary transmitted light, and occurs both in large crystals and

patches showing distinct cleavage, and also in aggregates of smaller elongated crystals apparently squeezed together with their longest axis in the direction of the foliation. The felspars are triclinic, and from the extinctions in some of the crystals, they appear to be anorthite, the angles made by the direction of maximum extinction with the edge formed by the faces o P and ∞ P∞ being 39° and 40°. Other felspar crystals in the section give, however, very different angles; one, for instance, extinguishes at 18° from the datum-edge in the + direction of Max Schuster, an angle which corresponds with that of brachypinakoidal sections of albite; but apart from the cases of anorthite, the extinctions in these preparations are not very trustworthy. A splinter of felspar taken from this specimen imparts, however, a very strong yellow colour to the blow-pipe flame, so that it is quite probable that albite is present.

Note *on the* Bouteillenstein, *or* Pseudo-chrysolite, *of* Moldauthein *in* Bohemia.

Bouteillenstein occurs in small irregularly shaped nodules and grains in sand near Moldauthein in Bohemia, in tuffs in the neighbourhood of Mont Dore les Bains, and Pessy, in the Auvergne, and in one or two other localities. These nodules have peculiarly pitted, corrugated, or wrinked surfaces, which I think are due to irregular glass enclosures and gas-pores, which, on the surfaces of the nodules, have been broken through and partially worn away. The glass of which these nodules consist is considered by Zirkel, Rosenbusch, Von Lasaulx, and others, to be one of the purest glasses occurring in nature. A section of a small bouteillenstein nodule, lent me by Prof. Judd, shows a considerable number of gas-pores and glass enclosures, and is traversed from one end to the other by distinct and approximately parallel banding, such as may be seen in many osbidians, but especially in a red one from the Yellowstone district, figured in vol. xxxvii. of the Quarterly Journal of this Society (pl. xx. fig. 2). In describing this specimen I noted that some of the bands showed very distinct depolarization between crossed nicols, and that extinction occurred when the bands were brought parallel to the principal section of one of the nicols. The bands in the bouteillenstein behave in a precisely similar manner, and in both cases the phenomenon may be attributed to strain*. The section contains numerous spherical gas-bubbles and irregular glass enclosures, some fusiform, others club-shaped, while many assume curious bulbous and slightly branching forms. They are frequently produced into, or from, delicate capillary rods, and they usually contain several, sometimes a dozen or more, spherical gas-bubbles. The surfaces of these glass enclosures do not, as a rule, appear to be smooth and cylindrical, but they

* Observations upon depolarization in connexion with strain are best made by artificial illumination, and the observer should screen all extraneous light from the eye. This may be done by wrapping a handkerchief round the eye-piece.

more resemble those of flint cores from which flakes have been artificially struck, or the surfaces of prisms of starch. They depolarize strongly from strain, and the glass immediately surrounding them is similarly affected, so that each glass enclosure is bordered by a nimbus which is traversed by dark brushes. The similarity of these glass enclosures to the one figured from the fulgurite of the Dom du Gouté is very striking. A great number of capillary glass rods pass obliquely through the preparation and are cut off by the planes of section, so that from a mere examination of the slide one can form only an imperfect estimate of the enclosures. The section shows one doubly refracting microlith, about $\frac{1}{200}$th inch in length, with a dark zone. A few other diminutive doubly refracting specks are also visible under a tolerably high magnifying power. Some of the gas-pores are large, and, through grinding, have become filled with emery mud. They thus fail to show the bright central spot, and merely appear as circular, black disks. What looks like a clear glass ball, containing a nearly opaque brownish sphere about $\frac{1}{8}$th of its diameter, and numerous minute angular granules, chiefly of glass, occurs in one part of the section. This ball is about $\frac{1}{50}$th inch in diameter, and causes a marked deflection of the banding in the adjacent glass; but in this case there is no strain developed, both the ball and the adjacent glass remaining dark during rotation between crossed nicols. I have no doubt that this is merely a hemispherical cavity (part of a gas-bubble) filled with Canada balsam and crumbs detached from the section during mounting. At another spot an opaque circular disk (part of a gas-bubble filled with emery) has also produced a deflection in the banding *. Although bouteillenstein is certainly a remarkably pure natural glass, the glass of the fulgurite from the Dom du Gouté is still purer, and while the former possesses a well-marked banded structure and a few microliths, the latter is absolutely structureless, so far as can be seen with an amplification of over 1000 linear. That bouteillenstein is an obsidian is denied by Makowsky †; but (apart from its banded structure) its glass enclosures and numerous gas-bubbles and its almost perfect freedom from any products of crystallization, render its comparison with fulgurite not merely admissible but possibly instructive. The bibliography of fulgurite consists, I believe, chiefly of notes by De Saussure and Humboldt, and more recent papers by Abich, G. Rose ‡, Gümbel §, Harting ‖, Römer ¶, Wichmann **, and Diller ††.

* That the strain in the bands results from a tension or stretching-out, and not from a compression at right angles to the direction of the banding, cannot be proved, since, in either case, one would expect an elongation of the gas-bubbles *by compression*. In this instance the pressure of the gas upon the wall of its cavity has been greater than the pressure upon the surrounding glass.

† Ueber die Bouteillensteine von Mähren ū. Böhmen, in Min. Mittheil. vol. iv. p. 43.

‡ Zeitschr. d. d. Geol. Ges. xxv. p. 112.

§ *Ibid.* xxxiv. p. 642.

‖ Soc. Batav. Amsterdam, 1873, p. 13.

¶ N. Jahrb. f. Min. 1876, p. 33.

** Zeitschr. d. d. Geol. Gess. xxxv. p. 849.

†† Amer. Journ. Sci. xxviii. p. 252

In concluding this short paper, I would express my sincere thanks to Prof. Judd for the trouble he has taken in preparing the sections upon which these observations have been mainly based.

EXPLANATION OF PLATE III.

Fig. 1. Globule of brownish fulgurite glass detached from the surface of a specimen of hornblende-gneiss. Summit of the Dom du Gouté, Chain of Mont Blanc. The globule shows a blow-hole at *y*, and its point of attachment at *x*. $\times 25$.

2. Fragment of brownish fulgurite glass broken from a bubble. It simply shows conchoidal fractures and some gas-bubbles. No trace of crystallization is visible in it. $\times 120$.
3. Fulgurite on hornblende-gneiss. The group of glass globules at *z* show a somewhat radiate distribution, and some of them are connected by a slightly vitrified trail. Natural size.
4. Glass enclosure containing numerous gas-bubbles occurring in fulgurite glass, broken from a bubble. $\times 250$.
5. Fulgurite adhering to surface of hornblende-gneiss. At *b* two gas-bubbles are seen in the fulgurite glass which incrusts the surface of the rock, but does not penetrate. The dark opaque part of the rock immediately underlying the fulgurite appears white when viewed by reflected light. Thin section, $\times 120$.

All these specimens are from the same locality. Figs. 1, 2, 4, and 5 are represented as seen under the microscope by ordinary transmitted light.

Discussion.

The President said that Mr. Eccles, in some of his Alpine ascents, had made a number of observations on the action of lightning on rocks, and had pointed out to himself an example of it on Monte Leone.

Prof. Boyd Dawkins had not seen any evidence from the paper that the fusion in these cases was due to lightning. He referred to the vitrification of rocks produced in vitrified forts and by beacons.

Prof. Judd referred to the discovery of fulgurite by Abich on the Little Ararat, and to the existence of other glasses without crystallites in Siberia, Iceland, and New Zealand.

The Author, in reply to Prof. Boyd Dawkins, explained that the rock could not, from its situation, have been fused by artificial means.

20. *On* Brecciated Porfido-rosso antico. By Frank Rutley, Esq., F.G.S., Lecturer on Mineralogy in the Normal School of Science and Royal School of Mines. (Read February 25, 1885.)

This well-known rock, the porphyrites of Pliny, the typical porphyry of the earlier, and one of the typical hornblende-porphyrites of more recent petrologists, has already been described in considerable detail by numerous writers, especially in an admirable paper by the late Prof. Delesse*. His observations upon a large number of specimens collected at Djebel Dokhan, the Porphyrites Mons of the ancients, by M. Lefebvre, are remarkable for the precision with which they were made at a period when the microscopic examination of thin sections of rock was unknown, or at all events in the very year (1850) when such sections were first made by Dr. H. C. Sorby.

The observations of Delesse were made chiefly with low magnifying-powers upon polished surfaces of the rock, and by reflected light. Brief descriptions of it, based on the examination of thin sections, have also been published in several works. On looking at a section recently prepared from a specimen of this rock, I was surprised to see that it consisted, not of a continuous section of hornblende-porphyrite, but of fragments of that rock held together by a micro-crystalline granular cement. On referring to Delesse's paper, I found that he described two kinds of the Porfido-rosso antico, one being the rock in its normal condition, the other a brecciated variety. It is to the latter that I would now direct attention.

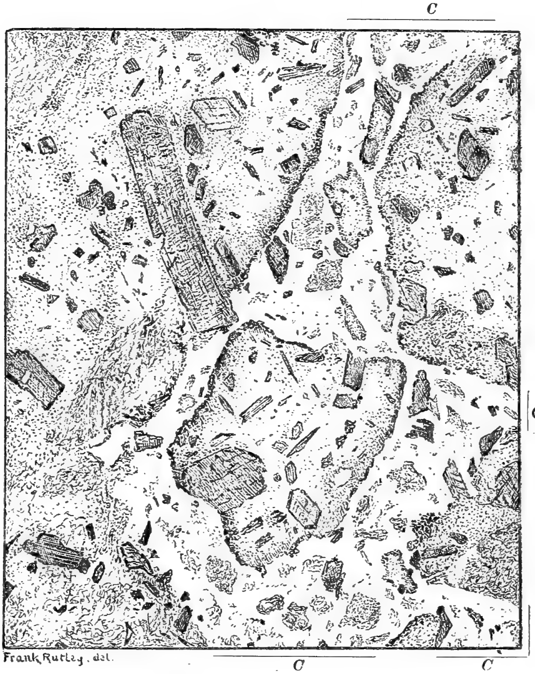
The specimen is of reddish-brown or maroon colour, flecked with small white or reddish-white crystals of felspar and dark hornblende crystals, which as a rule are considerably smaller than the felspars. It closely resembles the fig. 2 on the coloured plate attached to Delesse's paper. The section, when examined under a low power by ordinary transmitted light (see figure, p. 158), is seen to consist of angular and subangular fragments of hornblende-porphyrite ranging from about an eighth of an inch in diameter to very small dimensions, and surrounded in most cases by opaque borders of what appear to be dark granules. This bordering of the fragments and their frequently well-rounded angles suggest, at first sight, the idea that they are lapilli which have undergone superficial fusion. That they are true fragments there can be no doubt; for the hornblende and felspar crystals which lie on their margins are often irregularly broken away, while a fine débris of hornblende crystals, felspar crystals, and porphyrite ground-mass is scattered through the micro-crystalline cement which binds the fragments together. The ground-mass of the porphyrite looks as if it were crypto-

* "Recherches sur le Porphyre Rouge Antique et sur la Syénite Rose d'Egypte," Bull. Soc. Géol. de France, 2e série, t. vii.

crystalline, and has a bluish-grey tint, while the cement has a more coarsely crystalline texture, and is nearly colourless.

Brecciated Porfido-rosso antico (× 18; by ordinary transmitted light).

The siliceous cement is indicated on the margin by the letter *C* and a line. The distinctly-drawn crystals are chiefly hornblende.



The difference between the fragments and the cement is still more strongly marked when the section is viewed between crossed nicols.

When the section is placed on an opaque white ground and examined by reflected light, the fragments appear of a pale yellowish colour, and their borders, which by transmitted light appeared dark, now exhibit a deep yellowish or coffee-colour.

On a black ground by reflected light the fragments have a yellowish-red colour with a more intensely red border, in the outer edge of which there is usually a belt of yellowish-white opaque granules. The latter are apparently kaolinized felspar—similar granules, flecks and altered felspar crystals, occurring irregularly scattered through the interior of the porphyrite fragments.

The character of the borders of these fragments indicates decom-

position rather than fusion. The ground-mass of the porphyrite fragments, although possessing a finely granular or crypto-crystalline structure, appears very dark during rotation between crossed nicols; and from this it seems probable that it was once vitreous, and that there is still more or less of a glassy residuum.

The following extract from Delesse's paper shows that he was well acquainted with the brecciated character of this rock, although he could not then have seen it in the perfection with which it is demonstrated in microscopic sections:—"The structure of the Porfido-rosso antico is seldom completely uniform; it is often brecciated, as is the case in other porphyries, and especially in the melaphyres; the angular fragments which it contains are therefore simply varieties of the rock itself. These fragments are sometimes quite distinct from the paste which surrounds them, and from which they are sharply separated. Sometimes, on the other hand, they have no definite contours, and they melt imperceptibly into the porphyry." (A figure in illustration of this is appended to his paper, in which the brecciated character is merely indicated by the nesting together of the felspar crystals in irregular areas.) "One sees, in fact, that certain parts having angular forms are quite distinct from the paste, for they take a fine polish, have a slightly different colour, and contain larger and better-formed crystals of felspar. It is, however, impossible to distinguish the boundaries of porphyry-fragments corresponding to these angular patches; for it may be that they are fragments which have been fused, or stuck together (*ressoudés*), or that, the paste not having been brought to a state of complete fluidity and not having a uniform composition, the felspar was unequally developed in the rock." From a careful examination of the section already described, I do not think that this latter theory is tenable; and although the former might at first sight appear to be true, yet the decomposed character of the borders of the fragments contradicts such an hypothesis. As a rule, the fragments of a rock which has been crushed and recemented *in situ* would, if brought in contact, fit together accurately like the pieces of a puzzle. In the section before us there is a general correspondence of the disrupted parts, although, in some places, the fragments have become widely separated and possibly shifted slightly in a rotatory manner; while the alteration of some of the porphyritic felspar crystals into micro-felsitic matter, closely resembling the cement, tends, especially when such crystals lie on the borders of the fragments, to increase the impression that the neighbouring fragments would not fit together.

If the fragments were volcanic ejectamenta, there would be little or no appearance of their former continuity. Moreover, in this rock there is not the slightest admixture of material derived from other rocks, while in volcanic tuffs and dust one frequently finds that the constituent grains and lapilli are not all of one kind. Having, in the first instance, assumed, from the general appearance of the section, that the rock was a tuff, I have been gradually led to the conviction that its brecciated character is due simply to crushing

and to the subsequent cementing of the crushed material *in situ.* The finely comminuted porphyrite-substance which lies in the cement tends to prove this.

With regard to the power of resistance to crushing which this rock possesses, Delesse states that, compared with that of the red Egyptian syenite, it is as $2\frac{1}{2}$ to 1.

The ground-mass of the porphyrite-fragments, when magnified 250 linear, shows great numbers of minute granules and a smaller proportion of microliths. Most of the latter appear to lie with their longest axes parallel, from which it may be inferred that they are normal constituents of the porphyrite and not devitrification-products. The devitrification seems for the most part to be of a granular and not of a microlithic character.

Although the veins of cementing matter contain some felspar among the other finely crushed material derived from the porphyrite, I am inclined to regard it mainly as quartz. Delesse describes specimens of this rock in which very distinctly visible quartz-veins occur, one which he figures being certainly not less than an eighth of an inch in breadth at the broadest part. He states, however, that quartz is of rare occurrence in the Porfido-rosso antico. The same author observes, with regard to the constituent minerals of the rock that the felspars are triclinic and have a composition which is between that of oligoclase and andesine, that hornblende is present, and also specular iron and magnetite, the rock itself possessing a feeble magnetic power.

From a microscopic examination it appears that the felspars are much altered, in many cases containing what appears to be epidote. Rosenbusch describes a reddish alteration-product in the felspars of this rock, which he also is inclined to regard as epidote. He likewise mentions the occurrence of apatite*, of which some good crystals may be seen in the section here described. The magnetite occurs in octahedra, and also in irregularly shaped patches. I have been unable to get satisfactory measurements of the angles of extinction in the felspars, some crystals giving very small angles, while others extinguish at about 40° from the planes of composition of the twin lamellæ, and these must in all probability be anorthite. The majority, however, have low extinction-angles and are most likely oligoclase or andesine, as suggested by Delesse.

The hornblende-crystals are very perfectly developed, and few rocks contain more typical examples of this mineral. In one instance a hornblende crystal contains in its centre an irregular enclosure of quartz, and many of them envelope magnetite, either in octahedral crystals or in irregular grains.

The Porfido-rosso antico occurs at Djebel Dokhan in a vein from 20 to 25 metres broad, traversing pegmatite. Particulars concerning its mode of occurrence are given in the paper by Prof. Delesse already cited. Some sections lent to me by Prof. Judd show here and there

* 'Mikroskopische Physiographie d. massigen Gesteine,' p. 290: Stuttgart, 1877.

small siliceous veins in which minute "horses" of the rock occur; but the specimen from which they were cut is not of the brecciated variety.

Discussion.

The President pointed out that some of the antique sculptures of porfido-rosso in Italy show on their polished surfaces clear indications of a brecciated structure. He read the following passage from his journal during his stay in Florence, in December 1875:—"In one of the first rooms at the Pitti is a superb vase of porfido-rosso, a sort of saucer in form, about 8 feet across. This certainly is a breccia, being full of pieces angular and subangular, of different grain and crystallization, darker or lighter than the red matrix, also porphyritic, just like what one would expect a highly altered ash to come to, and the crystals had rather the appearance of that." At that time he was familiar with volcanic agglomerates, but not with crushed rocks; but he now thought Mr. Rutley's explanation was probably the right one.

21. *On* HOLLOW SPHERULITES *and their* OCCURRENCE *in* ANCIENT BRITISH LAVAS. By GRENVILLE A. J. COLE, Esq., F.G.S. (Read March 11, 1885.)

[PLATE IV.]

IT is now quite unnecessary to call attention to the fact that many of the Silurian "felstones" of North Wales were originally lavas of a highly glassy type. The investigation of their characters by Mr. Rutley * and Prof. Bonney †, and their comparison with volcanic rocks of far later periods, has fairly removed them from the convenient class of felstones, and given them a stricter position as altered rhyolites, trachytes, or obsidians. Perlitic, spherulitic, and banded structures have been recorded in them; the present paper deals with a structure which has been often noticed, and which is far more obvious to the eye, its original character being, however, veiled by much subsequent alteration.

Every one who has examined the group of Bala lava-flows in the Pass of Llanberis, notably at the foot of Esgair-felen, the great spur of the Glyder-fawr ‡, or on the slopes leading to Cwm-glas, must have observed whole masses of the compact grey rock crowded with white or brownish spheroids. These are especially conspicuous on weathered surfaces, or where a great joint-plane has made a section through some hundreds, their diameters ranging from less than a tenth of an inch to fully two and a half inches. Some are evidently radial aggregates, whether concretionary or amygdaloidal it would be hard at first to say; but others, and by far the most striking, are mere hollow nodules, giving the rock a coarsely vesicular aspect. Clear quartz-crystals often line the inner surfaces, and it is noteworthy that the matrix has frequently the schistose character so fully described by Prof. Bonney in the case of felsites near Bettws-y-Coed §. This may admit of considerable percolation of water and the deposition of minerals in cavities already formed. That these cavities are not, however, produced by indiscriminate weathering of the matrix, but have some connexion with the original condition of the lava-stream, is in places shown by the sharp demarcation between a nodular bed and that immediately succeeding it.

The solid spheroids, as a rule, seem composed of dense felsitic matter; if, however, they are not the result of the process of infilling that is in progress in the hollow nodules, the passage from one type to the other is so gradual that a complete explanation of the structure should cover both extremes.

Before entering into any details with regard to these ancient examples, it may be well to look for similar structures among com-

* "On Perlitic and Spherulitic Structures in the Lavas of the Glyder Fawr," Quart. Journ. Geol. Soc. vol. xxxv. p. 508; "On Devitrified Rocks from Beddgelert and Snowdon," Quart. Journ. Geol. Soc. vol. xxxvii. p. 403.

† "On some nodular Felsites in the Bala Group of North Wales," Quart. Journ. Geol. Soc. vol. xxxviii. p. 289.

‡ See Geological Survey of England and Wales, Horizontal Sections, Sheet 31.

§ Quart. Journ. Geol. Soc. vol. xxxviii. p. 291.

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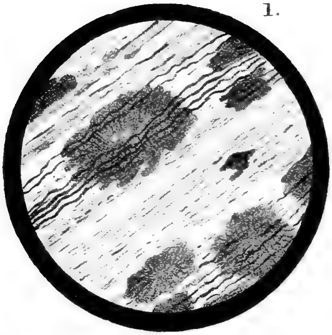

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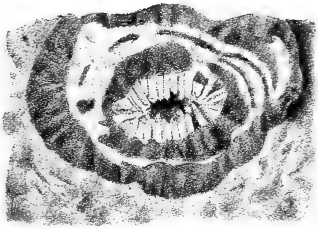

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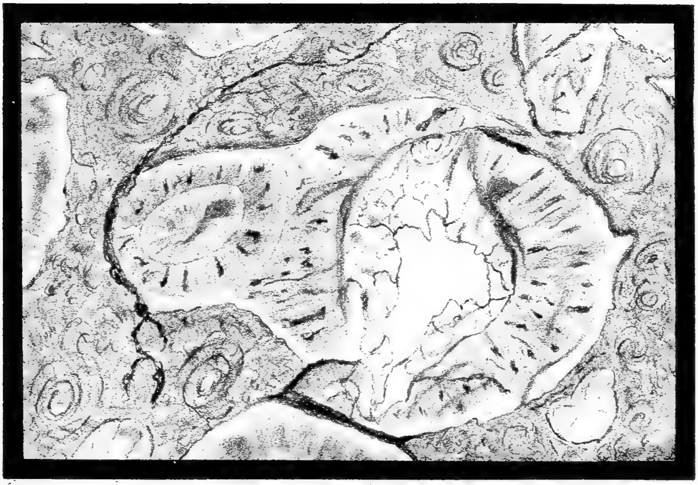

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A.J. Cole del. Parker & Coward lith. Mintern Bros. imp.

HOLLOW SPHERULITES.

paratively recent lavas. It appears that until 1860, certain unusually large segregations in the glassy rhyolites of Hungary had been classed with ordinary spherulites. In that year, however, Von Richthofen, in his paper entitled "Studien aus den ungarisch-siebenbürgischen Trachytgebirgen"*, considering that many of these bodies were hollow in the centre, and in some respects resembled the vesicles of scoriaceous lava, described them under the name of "Lithophysen." He believed that inclusions or segregations of highly siliceous matter had been, during the consolidation of the lava, blown up into bladder-like forms by the steam that they contained. The toughness of the surrounding glassy matrix prevented the immediate escape of the steam, and caused these vesicles to accumulate as hollow spheroids, their walls being formed from the original segregated matter. When cut across, their cavities are seen to be divided into chambers by dome-like lamellæ, one above the other, as if produced by successive expansions of the gas. In some cases the solid part of the "Lithophyse" is in a loose and powdery condition. The glassy matrix shows pronounced perlitic structure, and is often reduced to a mere honeycomb by the abundant development of the cavities.

Szabó, however, in 1866 †, represented the hollow nodules as nothing but altered spherulites, the removal of the material from the interior, partly in solution, partly as fine powder, having left a series of chambers which often follow the lines of the original concentric structure. He states that every successive stage of alteration is to be found, and believes that a gradual concentration of silica occurs in the layers that remain. These become finally strengthened by a deposit of quartz-crystals upon their surfaces.

It might still have been argued that the material found partially or even completely occupying the centres of these Hungarian spheroids was merely a product of infiltration; but in addition to chemical evidence given by Szabó, Karl von Hauer ‡ published, a few months later, analyses both of the ground-mass surrounding the "Lithophysen" and of their contents. His results may be thus compared:—

	Average of three Analyses of the Ground-mass.	Contents of the Lithophysen.
Silica	76·72	75·91
Alumina	12·72	14·98
Ferric oxide	1·80	
Lime	1·46	0·94
Magnesia	0·26	0·34
Potash	4·10	3·07
Soda	2·88	3·36
Loss on ignition	0·74	1·30
		99·90

* Jahrbuch der k.-k. geol. Reichsanstalt, 1860, p. 180.

† "Die Trachyte und Rhyolite der Umgebung von Tokaj." Jahrb. der k.-k. geol. Reichsanstalt, 1866, p. 89.

‡ "Die Gesteine mit Lithophysenbildungen von Telki-Banya." Verhandl. der k.-k. geol. Reichsanstalt, 1866, p. 98.

There is, then, no essential difference between the composition of the matrix and the solid portions of the nodules, and the latter are therefore far more likely to have been produced from the rock by devitrification during cooling than by any subsequent alteration.

Two determinations bearing out this view are given of the specific gravity of the groundmass, viz. 2·410 and 2·403, that of the material of the "Lithophyse" being 2·420. The figures expressing "loss on ignition" in the analyses may, slight as the difference is, suggest that decomposition has already begun in the devitrified portions of the rock.

J. Roth *, commenting on Von Hauer's analyses, fully agrees with Szabó in regarding the hollow structure as the result of the decomposition of spherulites, and this opinion appears to be generally adopted. Zirkel † has thus referred to "Lithophyses" from the Yellowstone area as "sphærolites nearly as thick as a walnut, that develop, by decomposition, the concentric layer-structure," all stages occurring "between sphærolites in the natural state and cavities in which there are five or six shells with their isolated borders." Mr. William Semmons has kindly allowed me the use of specimens showing similar features, which he collected from the obsidian cliffs of Beaver Lake.

E. Weiss ‡, dealing with a group of rocks from the Thüringian Forest, insists on the fact that here also the hollow spheroids met with are nothing but larger spherulites, and points out that the solid parts of both show radial structure in thin sections; but he returns towards the older theory of Von Richthofen in suggesting that material separating from a glass may be built up around a vesicle.

We are left, then, with two possible explanations of the hollow nodules found in lavas. Their outer and solid portion may safely be ascribed to spherulitic segregation from the matrix; but the inner cavity may be either the result of weathering upon a complete spherulite, or a steam-vesicle that has acted, like an included crystal or foreign body, as a centre of devitrification during cooling.

It does not appear that any real evidence has been brought forward in support of the latter view; but as a vesicular origin has been assigned to some of the Welsh nodular felsites §, and perhaps, by implication, to those of the Llanberis Pass, it may be well to inquire whether the decomposition of spherulites is not in reality sufficient to explain the characters of these rocks.

The determination of the conditions under which exceptionally large spherulites arise must be left to those who are studying the devitrification of artificial glass. Such forms are so frequently associated with small ones that the variation in size of the Silurian nodules is no evidence against their being all of common and

* Beiträge zur Petrographie der plutonischen Gesteine, 1869, p. 168. Also Allgemeine und chemische Geologie, 1883, vol. ii. p. 9.

† U.S. Exploration of the 40th Parallel, Microscopical Petrography, p. 212.

‡ Zeitschrift der deutschen geol. Gesell. 1877, vol. xxix. p. 421.

§ Quart. Journ. Geol. Soc. vol. xxxviii. p. 295.

spherulitic origin. There may be made out, however, among later lavas two classes of large spherules, which are merely extensions of structures familiar enough upon an ordinary scale.

We know, for instance, how in many obsidians the spherulites prove on microscopic examination to be mere cloudy aggregations, with perhaps the faintest trace of radial structure. Thus in a beautiful example from Iceland, numerous brown irregular patches are seen separating out along the lines of banding; since crystallization has not gone so far as to condense into microliths the globulites of which they are formed, these little nodules show the banding and even the fluidal structure of the matrix passing uninterruptedly through them. Their relation, indeed, to these probably earlier structures is that of concretions in sedimentary rocks to the beds in which they lie (Pl. IV. fig. 1).

In proportion as slower cooling allows of the radial grouping of the constituents, so the drawing together of the material towards a centre tends to sharpen the limit between the spherulite and the glass, until a crack is often the result. Usually, however, the outer border of even these well-marked forms contains a large amount of glass, and frequently concentric coats of similar cumulitic and glassy matter intervene between the radial zones.

Taking now sections of the obsidian with "Lithophysen" from Beaver Lake, we find in places no distinct boundary between the grey nodular aggregations and the banded structure of the glass (Pl. IV. fig. 2). The lines of minute spherulites run into the larger felsitic masses; and the latter, though probably somewhat altered since the consolidation of the lava, contain throughout the same rod-like form of crystallites as is abundant in the surrounding matrix. The felsitic substance is distinctly cryptocrystalline, its ill-defined particles polarizing in colour; and a very rough attempt at concentric arrangement occurs in portions of the nodules, the lines being brought out in hand-specimens by unequal weathering. Such irregularly bounded nodules may be broadly regarded as segregations of rhyolite in rhyolite-glass. They are localizations of such stony material as, in longer process of cooling, might have finally spread throughout the mass.

The equally irregular central hollows bear no resemblance to steam-vesicles, while signs of alteration are very evident in the felsitic matter round them. Flakes of hæmatite, red by transmitted light and giving an iron-reaction before the blowpipe, are developed in the powdery mass; and the beautiful rod-like crystallites, clear and colourless in the matrix, have, in these decomposing nodules, been either converted into or replaced by a red-brown ferruginous product. While the specific gravity of the glass is 2·41, that of the nodule, obtained by means of the bottle, is only 2·31, a result pointing towards hydration of the constituents rather than towards such a concentration of silica as Szabó refers to in the case of the Hungarian "Lithophysen" *.

If, then, the nodular obsidian of Beaver Lake appears to reproduce

* Jahrb. der k.-k. geol. Reichs. 1866, p. 89.

on a large scale the imperfect type of spherulitic structure, the famous Hungarian examples bear the same relation to the concentric and well-marked radial types. The "Lithophysen" in a rhyolite brought by Prof. Judd from Lipari have affinities with both groups; and reflection will show that towards the centre of such a felsitic segregation as has been described the material may often tend to become more and more fully crystalline. Thus in smaller cases—an obsidian from Vulcano, for example—the colourless radial groups of crystallites form independent well-bounded spherulites in the midst of brown clouds of globulitic dust.

A superb example of hollow spherulitic structure occurs in an obsidian brought from Iceland by Mr. J. Starkie Gardner. The brown spherules, sometimes single, sometimes intergrown, show radial structure to the naked eye, and, as might perhaps be expected, a sharp crack divides their outer surfaces from the glass. Even in the cases one may meet with in breaking the specimen across, the inner cavities are often very large in proportion to the fibrous shell; but here, again, we see nothing of the smooth curving surface of a steam-vesicle. The microscope shows the solid portion of the spherules to consist of delicate radially grouped fibres, with some trace of a concentric structure near the outer margin. The inner extremities of these fibres are, as it were, frayed out, with signs of the formation of secondary minerals between them (Pl. IV. fig. 3). Everything, indeed, again points to the conclusion that the hollow structure is only a result of decomposition.

Now lava-streams are especially subject to the attacks of acid vapours, of steam, and of water of high temperature, during the later stages of eruption *, and the numerous cracks of the glassy varieties will afford access to all portions of their mass. The parts most likely to be affected are any felspathic crystals that may be included, the crystallites of magnetite that may have separated out, and the spherulites that are most differentiated from the glass.

Long ago Scrope † pointed out that such "globular concretions" are first acted upon by decomposition, and give rise to some of the forms of "variolite," though he does not definitely refer the hollow spherulites that he noticed in the perlites of the Ponza Isles ‡ to any process of alteration. The more developed their radial structure, the more planes of weakness will the spherulites contain; and at the very centre, where the individual fibres terminate, the decomposing agents will probably find good hold. At the same time the outermost layer of the spherule, between which and the glass there is often small cohesion, will become reddened with iron alteration-products and perhaps appreciably dissolved. Where radial and partly vitreous layers alternate, the former perish while the latter remain. This may be illustrated by banded obsidians from Lipari, in which all stages of the process can be made out easily with a

* Compare Judd, "Volcano of Schemnitz," Quart. Journ. Geol. Soc. vol. xxxii. p. 322.

† Considerations on Volcanoes, 1825, p. 118.

‡ Trans. Geol. Soc. series ii. vol. ii. pp. 202 and 218.

lens; and there can be little doubt that the original "Lithophysen" are records of exactly the same action. It is interesting to find very similar appearances in our ancient rhyolites of the Wrekin, the roughly concentric cavities formed by the weathering of large spherules becoming lined with crystallized quartz (Pl. IV. fig. 4). The red earthy fibrous centres of the ordinary Wrekin spherulites *, contrasting with their clearer borders, are probably similar evidence of the more ready decomposition of the radial and perhaps more basic portions.

The one difficulty of this view of the formation of hollow spherulites is the getting rid of the kaolin that will, in all probability, be formed. But, even if the alumina is not removed in soluble combinations, the extreme minuteness of kaolin-particles will enable them to enter and pass along the cracks of a vitreous lava with comparative ease. Perlitic fissures, to which the more obvious joints of a hand-specimen are veritable gullies, may at last become choked, but are none the less active as transporting channels. Some of them, in an interesting specimen brought by Mr. Carruthers from the Yellowstone area, measure from ·02 to ·06 millim. across; and the sharpness of their edges removes the suspicion that they may have been much widened by decomposition. Now large particles of kaolin, such as one may rub off altered felspar with the finger, may measure ·01 millim. and more; but the material washed down naturally from a granite area is seen to consist of specks far smaller, ·004, ·002, ·0015 millim. or less in diameter. The way in which kaolin-dust penetrates all the cracks of a decomposing granite, and even the planes of separation between different minerals, is fair evidence of its capacity for wandering from its parent source; and the frequent occurrence of "Lithophysen" in rocks showing perlitic structure may be due to the greater number of channels there provided through which the alteration-products may run their course †.

To return at last to the Silurian felsites of the Llanberis Pass, we find in microscopic sections ample proof of their spherulitic character and of the community of origin of both solid and hollow nodules (Pl. IV. fig. 5). The relics of radial structure are faint but indubitable, and the junction of the spherules and the glass is usually well defined. Quartz may be seen developing among the crypto-crystalline fibres, and brilliantly surrounding the central hollow when it occurs. But in place of this cavity in several cases are the remains of original smaller spherulites, apparently of more complete development than the surrounding felsitic nodule, and therefore more liable to decay.

* S. Allport, "On certain ancient devitrified Pitchstones and Perlites from Shropshire," Quart. Journ Geol. Soc. vol. xxxiii. p. 454.

† I cannot refrain from here referring to a case bearing, perhaps distantly, on hollow spherulites. In much-altered granite (luxullianite) boulders on the slopes above the inlet of Nanjisal, near the Land's End, many of the felspar-crystals are found to be nothing but hollow shells lined with well-developed quartz. In places this infiltered silica has entirely replaced the orthoclase and formed solid pseudomorphs that are completely deceptive at a distance.

Sometimes singly, sometimes in groups, these centres of the larger nodules point to the origin of much of the hollow structure ; while in other cases, just as in the Yellowstone obsidian, the decomposition may have ramified through fairly uniform segregations.

The matrix, now much altered, is magnificently perlitic, and the removal of any kaolin would thus prove easy ; but the rock is also rudely cleaved, the spherules themselves have occasionally been faulted, and ample time has been allowed since the dying-out of Snowdonian fumaroles and hot springs for the work which, doubtless, began to be silently carried on to our own day. If, as I hope, one of the more perplexing structures of our ancient lavas may be adduced as additional evidence of their similarity to those of modern days, the object of these notes will have been amply served. It is probable, however, that no petrographical characters, nothing, indeed, short of stratigraphical evidence and comparison from point to point, can absolutely define the relations of an igneous mass. The orbicular segregations of a deep-seated rock, classed as spherulites by Vogelsang, but defined as "belonospherites" rather than "felsospherites" *, might in time give rise to hollow nodular structure. On the other hand, the complete demolition of the spherulite, an operation going on in the Icelandic specimen of Mr. Starkie Gardner, may in future ages reduce such a rock, whether it occur as an interbedded or intrusive mass, to the level of a scoriaceous obsidian or an amygdaloid.

In conclusion, my best thanks are due to Prof. Judd for kind help and many illustrative specimens, and also, as before mentioned, to Mr. William Semmons. Most of the rock-sections referred to have been prepared in the Geological Laboratory of the Normal School of Science and Royal School of Mines.

EXPLANATION OF PLATE IV.

Fig. 1. Section of obsidian from Iceland, with ill-defined spherulites developing along the lines of banding. × 12.

2. Section of obsidian from Beaver Lake, Yellowstone Park, for comparison with the above, showing part of the outer margin of a large hollow spherulite, with the banded structure of the glass passing into it without interruption. Some of the bands are composed of minute spherulites. × 7.

3. Section of part of the inner margin of a large hollow spherulite in obsidian from Iceland, showing a tendency to the formation of secondary minerals between the fibres of which it is composed. × 75.

4. Broken surface of altered rhyolite from the Wrekin area, showing large spherulite with structure characteristic of "Lithophysen," the cavities being lined with crystallized quartz. × $1\frac{1}{2}$.

5. Section of large hollow spherulite in altered perlite from Esgair-felen, Pass of Llanberis. The left-hand portion contains an inner nucleus with well-marked radial structure; the right-hand portion contains an irregular cavity partly filled with quartz. × $5\frac{1}{2}$.

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* Die Krystalliten, p. 134.

Discussion.

Mr. Rutley bore testimony to the careful observations of the author of the paper. The only cases in which he felt any doubt were those in which the irregular form of the nodules did not seem to be altogether reconcilable with their spherulitic origin.

The President was not able entirely to agree with the author; for while his explanation might account for some of the structures, yet many seemed to be due to an original vesicular character of the lava. He adduced cases which he thought could only be accounted for by the expansion of vapour-bubbles in a glassy rock, disturbance of equilibrium being capable of inducing crystallization.

The Author stated that he did not intend to apply his explanation generally, but only to the cases he had examined. Some of the irregularities in the form of the spherulites are due to crushing and faulting of the rock in which they are enclosed.

22. *On some* NEW *or* IMPERFECTLY KNOWN MADREPORARIA *from the* GREAT OOLITE *of the* COUNTIES *of* OXFORD, GLOUCESTER, *and* SOMERSET. By ROBERT F. TOMES, Esq., F.G.S. (Read January 28, 1885.)

[PLATE V.]

THE present paper is the result of continued search for Corals in the Great Oolite, and must be taken as supplementary to the one I have already published in the Journal of the Geological Society*. As the information it contains is wholly supplementary, I do not deem it necessary that a systematic classification of the species should be very closely observed.

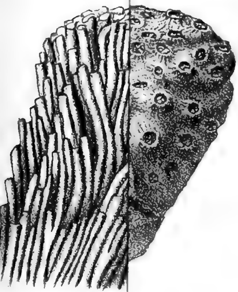
A section will be given of the Great Oolite at Milton, Oxfordshire, where a coralliferous bed is exposed, and one also of the quarry near Cirencester, from which the late Mr. Brown obtained most of the Oolitic Corals which were given by him to the Oxford Museum. These sections, accompanied by an enumeration of the corals obtained from them, and some sections in the neighbourhood of Bath, with the species they have yielded, constitute the principal part of the paper. To this will be added notes and descriptions of some of the species.

The genus *Bathycœnia*, and its allies, I have already shown to be characteristic of the Cornbrash; but three specimens of *Bathycœnia Slatteri* have lately been found at Combe Down, Bath; and its presence there, taken in connection with the prevalence of the well-known Bradford-clay Encrinite in the corresponding coral-beds of Farley Down and Hampton Down, would seem to point to a higher geological level for the coralliferous deposits around Bath than I have hitherto attributed to any of the Oxfordshire coral-beds. At the same time it is desirable that I should mention the occurrence of *Bathycœnia Slatteri* in the Great Oolite of the railway-cutting near Rollright, where it was found by Mr. Jas. Windoes, of Chipping Norton, though its exact position in the section has not been ascertained. Moreover, as I shall point out further on, there are some stratigraphical reasons for believing the coral-bed at Caps Lodge, near Burford, where also the same species of *Bathycœnia* has been met with, and those near Bath, to be of nearly the same age.

Some genera of Madreporaria, hitherto unknown in the Oolites of this country, have been recently met with, and will now be added to the list of genera. They are *Barysmilia*, *Stylosmilia*, *Heliocœnia*, and two new genera which I have designated *Thamnocœnia* and *Platastræa*.

Since the publication of my several papers on the Madreporaria of the Jurassic formations of this country, Prof. Duncan has brought out his "Revision of the Families and Genera of Sclerodermic Zoantharia"†. It is a valuable compilation, which by bringing together a great number of references to the works of other zoophytologists, past and present, renders the literature of the subject, comparatively speaking, simple and easy. How fully the classification therein set forth by

* Vol. xxxix. p. 168. † Journ. Linn. Soc. vol. xviii. Nos. 104–105, 1884.



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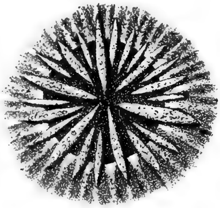

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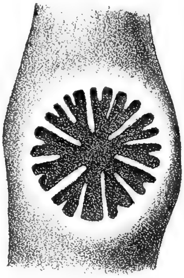

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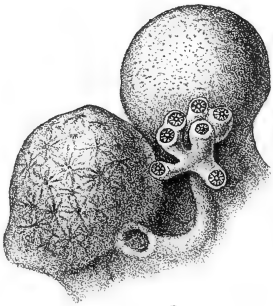

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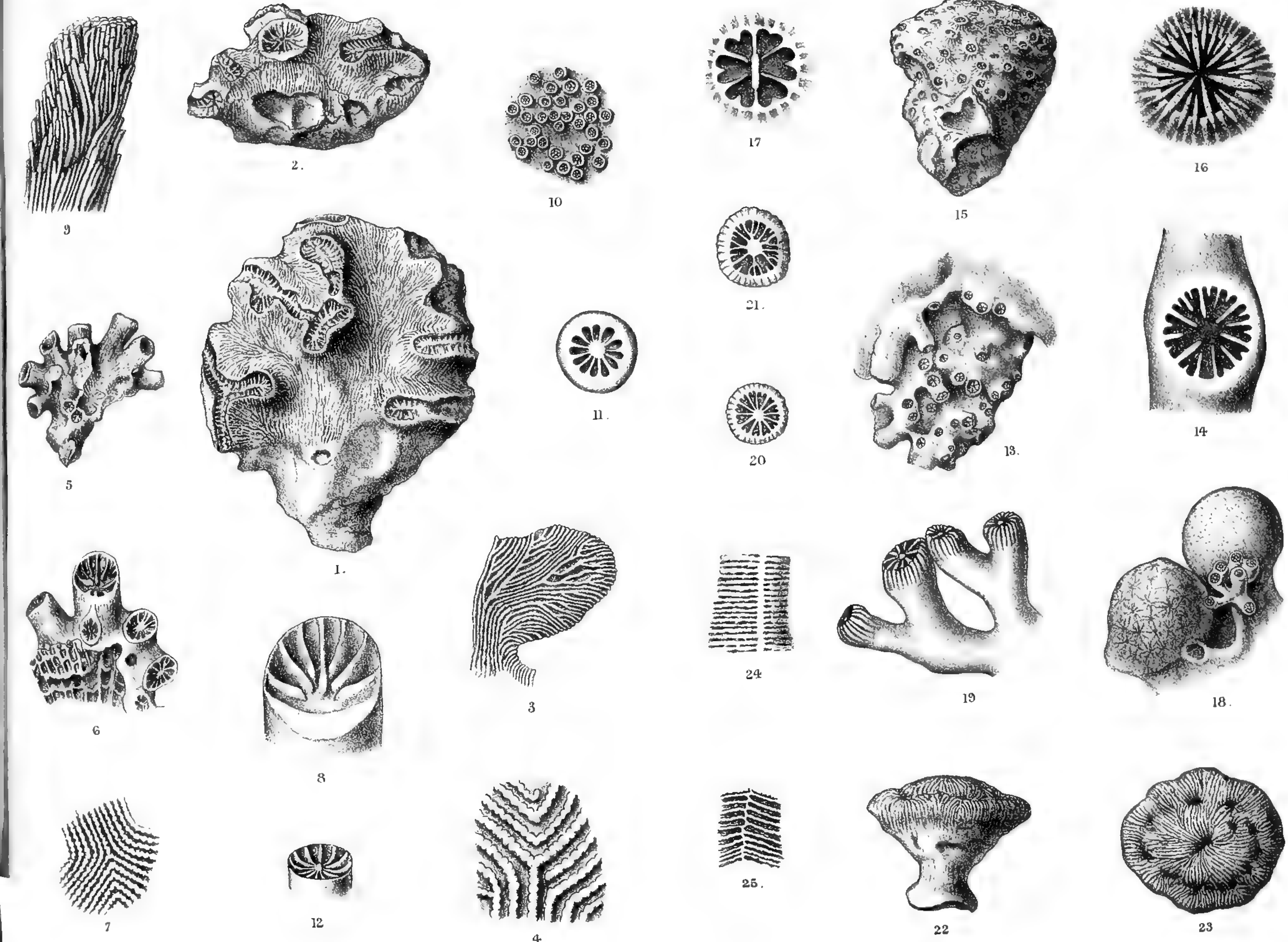

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GREAT-OOLITE MADREPORARIA.

Prof. Duncan will meet with acceptance at the hands of other workers in the same field, cannot at present be stated; but it may be confidently asserted that in some particulars serious modification will be imperative.

Section in Groves's Quarry, near the Village of Milton.

	ft.	in.
1. Surface-soil and shattered stone	3	0
2. Shattered stone, white, fine-grained, and scarcely oolitic in texture, containing a few scattered fragments of corals and a *Nerinæa*	3	0
3. Marly clay of a bluish colour	2	8
4. Coral-bed. A light-coloured, fine-grained, hard limestone, not oolitic, and almost ringing when struck with a hammer	2	7
5. Marly clay with a bluish tinge	1	0
6. Stone in large blocks	1	0
7. Ferruginous marly clay	2	4
8. Stone in blocks	2	0
9. Marly clay with a bluish tinge	1	6
10. Soft imperfect stone with argillaceous seams, containing *Cypricardia, Natica, Modiola*, and *Ostrea*	1	10
11. Marly shale with *Modiola* and *Ostrea*	3	1
12. Soft imperfect stone	1	2
13. Marly shale with *Ostrea*	2	3
14. Imperfect stone, harder than no. 13	1	9
15. Marly shale, much filled with comminuted shells of *Ostrea*	1	10
16. Imperfect stone	1	4
17. Marly shale with *Ostrea* in extreme abundance	3	3
18. Rubbly stone in about eight layers, without either shale or clay between them	4	0
19. Marly shale, grey and ferruginous, sometimes indurated, and having *Ostrea* in extreme abundance	3	3
20. Dense oolitic limestone of a yellow colour, and having oblique lamination. It contains comminuted fossils, chiefly shells, in extreme abundance	11	8
	54	6

The following Madreporaria have been taken from bed number 6 of the above section:—*Cryptocœnia*, sp., *Montlivaltia caryophyllata, Montlivaltia*, a species having a naked costulated wall, *Chorisastræa obtusa, Adelastræa magnifica* ?, *Isastræa limitata, I. gibbosa, Thamnastræa Lyelli, Anabacia complanata, Microsolena excelsa.*

From the nearness of the above section to the outcrop of the Great Oolite, and consequently to the underlying Inferior Oolite, it is more than probable that it corresponds more closely with the section exposed in the railway-cutting near Stonesfield than with the one at Caps Lodge near Burford, though the latter is only distant from it about a mile. But there is further and more direct evidence favouring the conclusion that the Caps Lodge and Milton sections, with their respective coral layers, do not correspond with each other in time. The Milton quarry is undoubtedly the one mentioned by Mr. Hull at page 58 of the Memoir of the Geological Survey, illustrating sheet number 44 of the map, in these words:—"On Milton field, in a large quarry, a section similar to that at Windrush is exhibited. There we find about 17 feet of interstratified marls, shales, and thin-bedded limestones, highly fossiliferous, resting on thick-bedded oolite more than 12 feet thick, and

yielding large blocks, the one belonging to the upper zone, the other to the lower."

Bed number 20 of my section is the thick-bedded oolite mentioned by Mr. Hull, and constitutes the lower zone, and this, he further on says, is the equivalent of the Stonesfield Slate. All above it (having, however, a much greater thickness than is stated by him) corresponds with the upper zone. The oyster which is so abundant in beds 17 and 19, and which occurs also in some of the other beds, is probably *Ostrea Sowerbyi*, and its prevalence in these beds, as well as the nature of the stone and shale of which they are composed, renders it quite probable that this part of the Milton section corresponds with the oyster-bed in the Stonesfield cutting. If such is the case, and the compact oolite below is identical with the Stonesfield Slate, further evidence in proof of the identity of the Stonesfield and Milton coralliferous deposits is unnecessary.

There is, however, considerable dissimilarity between these two coral beds; the one at Milton being much more uniform in texture, as well as much harder than the one at Stonesfield. The former is, indeed, so compact a stone, that it is only by fortunate fractures that the enclosed corals can be examined; and what adds more to the difficulty of securing satisfactory specimens is their highly crystalline condition. This coralliferous layer does not, indeed, present the usual characteristics of a coral bank, but rather resembles some near deposit into which they have been removed from the place of their growth.

My previous assertion that some of the corals figured by Professor Duncan, from the collection of the late Mr. Brown of Cirencester, came from Fairford, has met with partial corroboration. Two of the species, *Chorisastræa obtusa* and *Cryptocœnia tuberosa*, do not occur in the quarry from which Mr. Brown's collection was made, and are not to be seen in the collection given by him to the Museum at Oxford. The species were, I do not now entertain the least doubt, originally in Miss Slatter's collection, and had been obtained from Fairford.

A visit recently paid to Cirencester gave me the opportunity of inspecting the lime-kiln quarry, three miles along the Stroud road, and of preparing the following section which appears in it. It was from this quarry that Mr. Brown obtained his specimens.

	ft.	in.
1. Surface-soil	1	6
2. Soil and shattered stone	1	6
3. A soft friable bed of an earthy nature, of a deep yellow colour, and containing rubbly nodular stone. A species of *Echinobrissus* occurs in it	1	6
4. Hard, fine-grained, whitish stone, non-oolitic, with a somewhat conchoidal fracture, and penetrated by tortuous, but more or less vertical and anastomosing perforations, which are filled with the soft earthy part of the bed above. No fossils observed	2	9
5. Fine-grained oolite of a light yellowish colour, in some parts nearly white. Fossils rare	3	0
6. Coral-bed. Resembles the last, but is a little coarser. Contains a *Nerinæa* and other univalves, and about 15 or 16 species of corals	2	0
7. Compact yellow oolite with very few fossils	2	0

Bed 4 is very peculiar. It is honeycombed through and through with large perforations, and where the soft in-filling of the hollow places has weathered out, is much used for rustic rockwork.

Beds 5 and 6 are very much alike, and the latter might almost be regarded as the bottom part of number 5, but they have been separated in the section to define more exactly the position of the corals.

I have determined the corals from bed 6 as follows:—*Stylosmilia reptans*, n. sp., *Stylina solida*, *S. conifera*, *Cryptocœnia*, sp., *Convexastræa Waltoni*, *Isastræa limitata*, *I. gibbosa*, *I. Beesleyi*, *I. tuberosa*, *Latimæandra lotharinga*, *Latimæandra*, sp., *Cladophyllia Babeana*, *Thamnastræa Lyelli*, *Thamnastræa*, sp., *Anabacia complanata*, and *Microsolena excelsa*.

The examples of *Isastræa gibbosa* are singularly fine, and one of them, forming part of Mr. Brown's collection, now in the Oxford Museum, is very remarkable. It has long radiating finger-like processes springing from the original gibbous mass.

The most abundant coral in the Lime-kiln quarry is *Convexastræa Waltoni*. One specimen obtained by Mr. Brown is more than a foot in height, and consists of a mass of parallel corallites, apparently all springing from one base; so far as I could see, none of them were ramified.

A small and delicately formed *Stylosmilia*, which has also been met with at Farley Down near Bath, occurs with the *Convexastræa*; and the association of the two species, here and at Farley Down, would seem to indicate that the coral-beds of these two localities may be identical.

The want of a more extensive collection of Great Oolite corals from the neighbourhood of Bath, from which district so many of the types of MM. Milne-Edwards and Haime were derived, as well as of a more intimate personal knowledge of the strata from which they were taken, has long been an obstacle to me, not only in working out the stratigraphical distribution, but also in the determination of the species of Great Oolite corals. This want has now been in a great measure relieved by recent examinations of the exposures on Farley Down, Combe Down, and Hampton Down. These are the particular localities, it may be remembered, which furnished many of the specimens from which MM. Milne-Edwards and Haime drew up their descriptions of Great Oolite corals. The results of researches, made in company with my friend and frequent companion in the field, Mr. T. J. Slatter, and with the Rev. H. H. Winwood, I will now proceed to give.

In a rather extensive and long-since abandoned quarry on the south side of Combe Down is the following section:—

	ft.	in.
1. Surface-soil and shattered stone	4	0
2. Compact yellow stone	3	0
3. Hard yellow stone divided into 3 or 4 layers, and containing a few corals	5	0
4. Yellowish oolitic stone, much bored vertically by Annelides ?, but containing n corals	1	0
5. Coral bed. This very closely resembles bed 4, and like it is bored vertically ... 5 to	6	0
6. Bath Oolite, light in colour and oolitic in texture, containing very few fossils and forming the bottom of the quarry. Depth not ascertained.		

The following are the species which have been found in the above coral-bed by Mr. T. J. Slatter and myself:—*Enallohelia socialis*, n. sp., *Bathycœnia Slatteri*, *Thamnocœnia oolitica*, *Scyphocœnia*?, *Barysmilia Etalloni*, *Stylosmilia excelsa*, *Stylina Ploti*, *Cryptocœnia Pratti*, *Convexastræa Waltoni*, *Montlivaltia caryophyllata*, a *Montlivaltia* with a naked costulated wall, *Calamophyllia radiata*, *Isastræa limitata*, *I. serialis*, *I. microphylla*, *Latimæandra*, sp., *Chorisastræa obtusa*, *Platastræa Conybeari*, *Oroseris Slatteri*, *Dimorphastræa fungiformis*, n. sp., *Anabacia complanata*, *Microsolena excelsa*.

The bed in which the corals occur has not at all the appearance of a coral-bed, properly speaking, but is like a deposit into which the corals have been drifted from some near coral-bank and scattered about, not in any place thickly, though they are not anywhere absent. It is a distinctly oolitic layer, and the round grains of which it is composed, as is not unusual in the Great Oolite, have eaten into the imbedded organisms, and destroyed their external details. Such is the condition of many of the corals from the Great Oolite of Combe Down, though occasional specimens may be met with which are in a fair state of preservation.

Of the exposures on the Hampton Downs, I am unable to give detailed sections; but at the south end of that plateau are some ancient and abandoned excavations, which are usually denominated the Hampton Rocks, in the upper part of which is a bed which, from the abundance of sponges it contains, was called by the late Mr. Moore the Sponge-bed. Immediately overlying it is the surface-soil, mixed with a considerable quantity of shattered stone. This is a broken-up coral-bed containing many corals. They are mostly in a bad state of preservation; and as very few could be determined satisfactorily, a list of the species has not been prepared.

There is also on the same ridge, northward of the Hampton Rocks, a large and disused quarry lying immediately behind the rifle-butts, and now known as the Butts-quarry. In the upper part of it is a well-marked coralliferous layer. It is three or four feet above the beds of dense and massive building-stone for which Bath has been so long and justly celebrated. From it have been procured the following corals:—

Stylina Ploti, *Cryptocœnia microphylla*, *Convexastræa Waltoni*, *Montlivaltia*, sp., *Isastræa explanulata*, a massive variety, *Chorisastræa obtusa*, *Thamnastræa scita*, *Thamnastræa*, sp., *Oroseris Slatteri*, *Dimorpharæa*, a small species, *Comoseris vermicularis*, *Anabacia complanata*, *Microsolena excelsa*.

Across the valley, eastward of the Hampton Downs, near to the village of Bathford, and directly under the building called Brown's Tower, is a quarried escarpment which constitutes the western boundary of Farley Down. From this spot, as I learn from the Rev. H. H. Winwood, the late Mr. Walton obtained his Farley-Down fossils.

The coral-bed is here more fully developed than in the Hampton-Down quarry, or than at the Hampton Rocks. Varying in thickness from two feet to ten feet, it possesses all the peculiarities observable in such Inferior-Oolite coral-deposits as Crickley and the Horsepools, near Cheltenham, being a fine-grained and light-coloured mudstone, which in some places is somewhat brecciated. It corresponds precisely in position with the coral-beds on the south-west side of the valley, appearing immediately above the massive building-stone. In several places above the escarpment, where the surface of the turf has been broken through, thin patches of Forest Marble are exposed; and it would therefore seem that as the coral-bed occurs only a little way below that bed, and as it contains many fragments of the well-known Bradford-clay Encrinite, it holds a higher geological position in the Great Oolite than has been assigned to the Oxfordshire coral-beds, if we except the one at Caps Lodge near Burford. From the Farley-Down exposure I have obtained the following corals:—

Stylosmilia reptans, n. sp., *Stylina Ploti*, *Crytocœnia microphylla*, *Convexastræa Waltoni*, *Heliocœnia oolitica*, n. sp., *Montlivaltia caryophyllata*, *Isastræa limitata*, *I. explanulata*, *I. microphylla*, *I.* sp., *Latimœandra lotharinga*, *Chorisastræa obtusa*, *Goniocora*, sp., *Thamnastræa scita*, *T. Waltoni*, *Comoseris vermicularis*, *Oroseris Slatteri*, *Dimorpharæa*, sp., *Anabacia complanata*, *Microsolena excelsa*.

All the species from this, as well as other places in the Bath district mentioned in this paper, have been obtained from their respective localities and beds by Mr. T. J. Slatter and myself.

Enallohelia socialis, n. sp. (Plate V. figs. 13, 14.)

The corallum consists of a great many corallites proceeding from a common root, which is of small extent. From this they grow upward and outward in every direction, and form a very thick and tangled mass from one to two inches in height, and three or four in breadth. This has a very irregular but somewhat convex upper surface, formed by the union of the corallites, which are thus fused into a more or less compact mass. The corallites are thin and maintain nearly the same diameter throughout. They ramify in an irregularly alternate manner, but do so very much more thickly at their upper ends, where, coming into contact with others, many unite and form irregular masses, which have their upper surfaces more or less flattened. The mural costæ, which in some species of this genus are observable near the calices, and in connection with the septa, are in the present species nearly obsolete.

Very few calices appear on the lower part of the corallites, but on the upper surface they are thickly but irregularly scattered. All the prominent ends of the corallites, and all the axial spaces have

calices, and others occupy flattened areas formed by the union of the corallites. They are circular and have very little prominence, the walls of the corallites continuing quite to the calicular margins.

The septa are not exsert; there are three cycles, and the septa of the first, six in number, approach the fossula, which is rather deep; those of the second cycle are three fourths of the length of the primary ones, and those of the third cycle are very short, almost rudimentary.

Several specimens have been taken from the coral-bed in the Combe-Down quarry, all of which come well within the foregoing description, though they vary somewhat in their relative height and breadth.

From *Enallohelia compressa* and *E. clavata*, with both of which the present species agrees in the number of primary septa, it nevertheless differs considerably: from the first, in its general habit of growth; and from the second, which, however, it more nearly resembles, in not having exsert septa, in having the third cycle of septa rudimentary, and in the absence of the enlarged inner margins of the primary ones. There is no other species of the genus with which it is likely to be confounded.

Bathycœnia Slatteri, Tomes.

Some ill-preserved examples of this coral have been taken from the coral-bed on Combe Down by Mr. Slatter and myself. A single worn specimen has also been obtained from the Great Oolite at Caps Lodge, Burford, and is now in Mr. Hudleston's collection of Great-Oolite corals from that and other localities in Oxfordshire.

Great doubt is expressed by Prof. Duncan, in his "Revision of the Families and Genera of Corals," as to the distinctness of *Bathycœnia* from *Stylosmilia*, which genus, in habit of growth, it somewhat resembles. A careful comparison of well-preserved specimens of Tertiary *Stylosmiliæ*, in my own cabinet, with *Bathycœnia* was made by me when drawing up the generic definition of the latter, and the absence of a true columella was clearly made out. The accuracy of my diagnosis has been fully confirmed by the discovery of a *Bathycœnia* in which the septa do not meet in the centre of the visceral cavity, and in which therefore there is no columella*.

Genus Thamnocœnia, n. g.

The corallum consists of an irregularly formed and attached mass of compact cœnenchyma, from which corallites spring and present the appearance of a straggling ramified cluster.

The corallites have considerable prominence, the longest being fully half the height of the corallum. The intercalicular portion, as well as the free part of the corallites, is wholly without epitheca, and has long and equal costæ.

The calices are deep and circular. The septa are entire and the

* Since the above was written, I have detected tabulæ in the calices of a specimen of *Bathycœnia Slatteri*.

primary ones swollen at their inner margins, somewhat as in *Scyphocœnia staminifera.*

Increase takes place by gemmation, quite at the base of the corallites, probably from the basal cœnenchyma, but not on any other part of the corallum.

In its general form the only specimen I have seen bears considerable resemblance to the small and not much developed examples of some species of *Dendrophyllia,* but only superficially, its affinities being with the family Astreidæ, while the absence of denticulations on the margins of the septa indicates a place in the subfamily Eusmilinæ.

THAMNOCŒNIA OOLITICA, n. sp. (Plate V. figs. 5–8.)

The corallum has an irregular basal part, which is broadly attached to a worn fragment of *Platastræa Conybeari,* on which it spreads, and which it partly covers. From this the corallites spring in a more or less upward and outward direction. Gemmation taking place at the base of the corallites gives to them somewhat the appearance of having been produced in pairs. They are prominent and cylindrical, but a little enlarged at their calicular ends. Both the corallites and the spaces between them have long, straight, and regular, but not prominent costæ, which extend from the margins of the calices downwards to the attached part of the corallum.

The calices are circular and deep, and their margins are prominent and thin. The septa are straight and project but little into the calice. They are wholly without denticulations, but those of the first and second cycles have their ends much swollen, a good deal as in the genus *Scyphocœnia.* Those of the first cycle are six in number, and extend very nearly into the fossula, which is small, circular, and distinct. The second cycle has septa which are very nearly as long as those of the first, and the remaining cycle consists of septa which are about three fourths the length of those of the second cycle. These have very little prominence, and are without the terminal swellings.

The full height of the corallum is about 9 lines. The diameter of the corallites is 2 lines. One specimen only has been met with; it was taken by me from the coralliferous layer on Combe Down, and was in near proximity to a specimen of *Barysmilia Etalloni.*

SCYPHOCŒNIA ?

I have obtained a coral from Combe Down, where it was associated with *Barysmilia Etalloni* and *Thamnocœnia oolitica,* which possesses some of the characters of *Scyphocœnia,* but differs from it in one very important particular. It bears considerable resemblance to *Scyphocœnia excelsa,* in the form and arrangement of the corallites, but the latter do not remain attached to each other excepting quite low down. The septa appear to resemble those of *Scyphocœnia excelsa,* and there are a few strongly developed tabulæ, as in that species. The specimen is, however, too much injured to permit of detailed description.

The following table will show the relationship which exists between some of the Oolitic *Eusmilinæ* which I have had occasion to speak of in my several papers on Oolitic Madreporaria.

EUSMILINÆ having the corallum

- simple; epithеca present; corallum
  - elongated .... CERATOCŒNIA.
  - discoid .... DISCOCŒNIA.
- compound; epitheca
  - rudimentary or absent; corallum
    - compact; corallum
      - hemispherical, turbinate, or lenticular; gemmation intercalicular. — BATHYCŒNIA.
      - curved, compressed, and attached by a point; gemmation lateral and terminal. — SCYPHOCŒNIA.
    - formed by a mass of cœnenchyma, from which the corallites spring and form a straggling ramified cluster; gemmation external and basal. — THAMNOCŒNIA.
  - well developed; the corallum bushy; gemmation lateral and terminal ... DONACOSMILIA.

NOTE.—Most likely the form for which I have suggested the name of *Depaphyllum* should be associated with the above genera.

Genus Barysmilia.

I have long known *Barysmilia* as a Cretaceous genus in this country; but until quite recently was unaware of its presence in the Oolitic formation either in England or elsewhere. Two examples were, however, taken by me during the present year (1884) from the coralliferous layer in the quarry on Combe Down, of which I have given a section. So long ago as 1859 M. Etallon made known the existence of three species of corals in the Corallian beds of the Haut-Jura, attributable to the genus *Baryphyllia* of M. de Fromentel *. That genus differs chiefly from *Barysmilia* in having denticulated septa. At present I am unable to observe the least evidence of denticulations on the septa of the specimens from Combe Down, and am compelled, therefore, to refer them to the genus *Barysmilia*. If, however, the specimens here mentioned have lost the denticulations of their septa, which is very probable, the already acknowledged Jurassic genus *Baryphyllia* will have to be substituted for *Barysmilia*.

Barysmilia Etalloni, n. sp. (Plate V. figs. 1–4.)

The corallum has an irregular subglobose form, a little higher than wide, the lower part being peduncular and attached by a small base.

The whole of the peduncular part, as well as the space around and between the calices, is ornamented with costæ, which are regular, long, and anastomosing, and, near to the calices, more or less papillated. On the lower part of the corallum they are less distinct and nearly smooth. In the bottom of the hollows, between the calices, there is sometimes a distinct line of demarcation between the costæ surrounding the several calices, which has something of a herring-bone arrangement.

The calices are rather distant, the intervals between them being in all cases greater than their own diameter; but they approximate most nearly to each other on the top of the corallum. They are extremely variable in length, and occur as a simple oval, shaped like a figure 8, like the letter S, or like a more or less irregular cross. The longest calice I have seen has a very serpentine form, which, if straightened out, would have sufficient length to pass over the whole of the corallum, from the base on the one side, in a line over the top, to the base on the other side. The margins of the calices are prominent; they are rather deep, and the septa are thin, irregularly developed, and continuous with the intercalicular costæ.

In a simple ovoid calice I can determine about fifty septa, about twelve of which, constituting the first and second cycles, pass into the fossula, where they unite and form a very irregular but dense columella, which in the long calices appears as a rugged but prominent line of very variable thickness, which is continued the whole length of the calice.

Stylosmilia reptans, n. sp. (Plate V. figs. 18–21.)

The corallum consists of short tufted masses, rarely exceeding an

* Etud. Paléont. Terr. Juras. Haut-Jura, p. 93.

inch in height, which are usually attached to some hard body, and over which they spread, in a manner which is the result either of basal gemmation, or of increase by means of stolons. Of several specimens now before me, one from Farley Down is attached to a weathered fragment of *Thamnastræa*, which it partly conceals; and another, from the Lime-kiln quarry near Cirencester, is parasitic on *Convexastræa Waltoni*, over which it spreads.

The corallites are small at their attachment, rather crooked, increase in size gradually, and attain to three fourths of their full height before freely branching out. This they do irregularly, though lateral gemmation apparently takes place about the same time in the several corallites. Once commenced, it proceeds with sufficient rapidity to form a crowded mass of corallites, the calicular extremities of which, however, have every degree of prominence, scarcely any two being of exactly the same height.

The walls of the corallites are thick, but do not extend to the margin of the calices, and there is no appearance of epitheca, but well-marked costæ which blend with the septa pass down the corallites, and become less distinct as they extend downwards.

The calices are circular and prominent, but there is a well-marked fossula. The septa are exsert and are continuous outwardly with the mural costæ. The first two cycles are well developed and pass into the columella; the third cycle has very short septa, which are scarcely a fourth of the length of those of the earlier cycles. The columella is large, styliform, and with a pointed apex, but is not very prominent.

Height of the corallum about 9 lines; diameter of the corallites about one line.

A specimen from Farley Down indicates, by the manner in which the corallites spread over the substance to which they are attached, the possibility, almost the probability, of increase by means of stolons. Some other examples, taken from the Lime-kiln quarry, Cirencester, present precisely the same peculiarities.

STYLOSMILIA EXCELSA, n. sp. (Plate V. figs. 9–12.)

The corallum consists of a dense mass of slender corallites, and very closely resembles those of *Calamophyllia radiata*, so closely, indeed, that the two species have been confounded. On nearer examination the corallites are seen to be a little less straight than in that species, and rather more densely placed. There is no trace of the long mural costæ which characterize *Calamophyllia*, the corallites appearing to be quite smooth. The walls are thick, and the calices appear to have been shallow, but none of them retain their margins. There are about 12 septa, which are thin and not very regularly developed. In some calices those of the third cycle join the older ones near to the columella, but more frequently all of them run into the columella; the latter is large and styliform. In some of the calices two opposite septa are much thicker than the others, which is suggestive of fissiparity.

The only specimen I have seen is of considerable size, and was

taken from the coralliferous layer in the Combe-Down quarry by my friend Mr. T. J. Slatter.

Genus Heliocœnia.

Heliocœnia, Etallon, Etud. Paléont. Terr. Jurass. Haut-Jura, p. 74 (1859).

Placocœnia, d'Orb. ?

M. d'Orbigny formed the genus *Placocœnia* from a cast of a coral somewhat like *Stylina*, but differing from it in having a lamellar columella. His description is very brief, and the genus is not sufficiently particularized for adoption, though there is some probability that the subsequently created genus *Heliocœnia* is identical with it.

The want of figures to illustrate Etallon's descriptions of *Heliocœniæ* has been supplied by M. Koby, in his fine work on the Jurassic corals of Switzerland*. Five species are therein figured, one of which, *Heliocœnia costulata*, Koby, has a small, styliform columella and appears to me to differ so much from the others as to be doubtfully referable to the same genus.

M. de Fromentel, while acknowledging the genus *Placocœnia* of M. d'Orbigny, does not admit *Heliocœnia*, but has created a very closely allied genus, *Stylohelia*. This latter has been merged into *Heliocœnia* by M. Koby.

Prof. Duncan, while reducing *Heliocœnia* to the rank of a subgenus, has placed it in his "Alliance Styloida"†, immediately following *Stylina*. The genus *Placocœnia*, which I have supposed to be identical with *Heliocœnia*, he introduces into another "alliance," which he designates "*Placocœnoida*." Further, he separates the genus *Stylohelia* entirely from the foregoing, and associates it, with *Enallohelia* and *Dendrohelia*, in the family Oculinidæ.

In direct contrast to the views of Prof. Duncan, M. Koby unites *Stylohelia* and *Heliocœnia* in one genus, giving the latter name the preference on account of its priority. With specimens of *Stylohelia mamillata* before me, which I have received from the Corallian of the Haute-Saône, I feel no hesitation in associating the genus *Stylohelia* with *Stylina* and other allied genera, but fail to observe any alliance whatever with the Oculinidæ.

Heliocœnia oolitica, n. sp. (Plate V. figs. 15–17.)

The corallum has a somewhat peduncular form, with an irregularly flat but not overhanging top. The calices are very unequally distributed over the whole corallum, but are very thinly scattered on the peduncular portion. On the top they are thinly placed, excepting where gemmation has taken place most recently, where they are rather crowded. They have not much prominence, and the intercalicular costæ, which are of nearly equal size, meet, but end abruptly in the middle of the intercalicular spaces.

The septa are exsert, and they and the costæ, with which they are

* Monogr. Polyp. Jurass. de la Suisse, p. 63 (1881).

† "Revision of Families and Genera," see pages 45, 110, and 197.

continuous, nearly conceal the wall, much as in unworn calices of *Convexastræa*. Those of the first cycle extend towards the centre of the calice, and have a slight swelling at their inner end. The septa of the second cycle are half the length of those of the first, while those of the third are half the length of the second.

The lamellar columella has very little prominence, and is so placed between two opposite septa of the first cycle as to fill up the space between them so closely that, when the calices are worn down, the whole becomes a continuous and straight line across the calice, dividing it in half. Both septa and septal costæ have their margins distinctly crenulated, the crenulations being small, pointed, and irregular. Their sides also are furnished with coarse irregular granulations, which are also observable in the spaces between them.

Height of the corallum 1 inch 6 lines; the diameter is about the same, and the calices are about 1 line in diameter. The spaces between the calices considerably exceed the diameter of the latter, excepting in one or two crowded spots.

Excepting the single example from Farley Down, I have not examined a species representing this genus.

Genus Convexastræa, d'Orb.

As *Convexastræa Waltoni*, our only representative of the genus, was described from specimens collected by the late Mr. Walton at the Hampton Rocks near Bath, it is, perhaps, desirable that I should state that I have compared specimens from that locality with others from the coralline deposits in the Great Oolite of Oxfordshire, and find them to be in all respects similar.

The differences between *Convexastræa* and *Cryptocœnia* have been recently defined with great clearness by M. Koby in his work on the 'Jurassic Corals of Switzerland,' now in course of publication. He observes that the former differs from the latter in having the septal costæ less numerous, rarely confluent, and not completely concealing the intercalicular spaces.

Genus Montlivaltia, Lamx.

I have often met, in the Great Oolite, with a supposed *Montlivaltia* which is characterized by a stunted form, a naked costulated wall, and rather a small number of very thin septa. The fossula is elongated, much as in *Montlivaltia caryophyllata*. The mural costæ are rather far apart, and have a prominence according to the order of the septa they represent. They are wholly without tubercles or papillæ, and if their smooth and rounded form may be taken as any indication of the nature of the margins of the septa, the latter may also have been smooth. In that case it could not be placed in the genus *Montlivaltia*. It occurs in the Great Oolite of the Rollright and Stonesfield railway-cuttings, in the Caps-Lodge and Milton quarries, and I have a specimen taken from the coral-bed on Combe Down. From none of these places have I obtained well-preserved specimens.

Genus Adelastræa, Reuss.

An objection was some time since raised by Reuss to the use of the unclassical name *Confusastræa*, and attention having been called to this by Prof. Duncan, it must now be abandoned. *Adelastræa*, the name applied by Reuss to a species from the Cretaceous beds of Gosau, will now take its place, and *Confusastræa consobrina*, *Confusastræa tenuistriata*, and *Confusastræa magnifica*, which I have introduced into our coral-fauna, must now be called *Adelastræa consobrina*, *Adelastræa tenuistriata*, and *Adelastræa magnifica*. Three other species which occur in the Great Oolite of the Boulonnais, one of which has been lately described by me under the name of *Confusastræa Rigauxi*, are now also to be referred to the genus *Adelastræa*.

Some very large specimens of a coral appertaining to the genus occur in the Great-Oolite quarry near Great Milton, and some of less dimensions have been taken from the Caps-Lodge quarry; but whether they are distinct from *Adelastræa magnifica*, to which they bear considerable resemblance, I have not yet been able to determine.

Genus Platastræa, n. g.

Clausastræa, Milne-Edw. and Haime, in part.

The genus *Clausastræa* is one of those in which there is ample scope for diversity of opinion, for it has been placed among the *Astreidæ*, among the now discarded *Tabulata*, and in the newly proposed half-way group designated *Plesiofungidæ*. It is now, however, evident that two very distinct forms have been confounded under the name of *Clausastræa*. In specimens of *Clausastræa dubia* and *Clausastræa Edwardsi*, with which I have been favoured by M. de Fromentel, there are, as mentioned by him in the description of the species *, very distinct and numerous tabulæ, arranged one above the other with great regularity, and extending on the same level across the corallum. They have been observed and figured in another species by M. Etallon, in which the same distribution and form are obvious †.

The other form is represented by two English species, one of which, from the Great Oolite of Combe Down, Bath, has been described by MM. Milne-Edwards and Haime under the name of *Clausastræa Pratti*. The endotheca of this species they describe in the following words:—"The loculi are closed by well-formed and rather numerous dissepiments." In the figure which accompanies the description these are shown ‡. In weathered specimens from Combe Down, now before me, the nature of these dissepiments is very apparent. They are obviously quite unlike tabulæ.

Under the impression that the so-called *Clausastræa Pratti* has an essential columella, the original describers transferred it to the genus *Plerastræa*, in which genus it appears in their general work on corals. But from the examination of a number of specimens

* Introd. Etude Pol. foss. p. 281.

† Leth. Bruntr. pl. lvii. fig. 5.

‡ Brit. Foss. Cor. pt. ii. pl. xxii. fig. 5.

from Combe Down, I am convinced that the supposed columella does not exist in any of them, and that, as I shall presently show, they are identical with the *Isastræa Conybeari* of the same authors, from the same locality. In fact the supposed columella is nothing more than the blending together of the inner margins of the septa, which takes place in a very uncertain manner quite low down in the corallites, and becomes visible only when the corallum is much worn down. It was from such a worn specimen that the figure of MM. Milne-Edwards and Haime was taken. With the full conviction therefore that the Coombe-Down coral cannot consistently be placed either in *Clausastræa* or *Plerastræa*, I have created a genus for its reception which I define as follows:—

The corallum is massive and more or less globular. The calices are large and shallow; there is no wall surrounding the corallites, and the septa of one calice meet and unite with those of the adjoining ones. They are not numerous, and are strongly denticulated. There is no columella. The dissepiments are very numerous, completely filling up the loculi. They are well developed and strongly arched.

Platastræa Conybeari, M.-Edw. and Haime, sp.

Isastræa Conybeari, M.-Edw. and Haime, Brit. Foss. Cor. pl. ii. p. 113, pl. xxii. fig. 4 (1851).

Clausastræa Pratti, M.-Edw. and Haime, Brit. Fos. Cor. pl. ii. p. 117, pl. xxii. fig. 5 (1851).

All the specimens recently collected at Combe Down may be referred either to *Clausastræa Pratti* or to *Isastræa Conybeari*, according to the condition of the specimen examined. In its normal form this species is more or less globose, and in such specimens, when not too much worn, the calices have much the form and appearance of those of *Isastræa Conybeari*. But frequently the corallum has departed from this regularity of outline, and the departure has been accompanied by a corresponding irregularity in the form of the calices, and in the degree of development of the septa where they meet in the fossula. Such specimens, if much worn, present all the appearance of *Clausastræa Pratti*; and indeed the characteristics of both the supposed species may sometimes be observed on different parts of the same corallum.

Goniocora, sp.

I have met with a single specimen referable to this genus, which in size, mode of growth, and so far as can be seen in its calicular characters, bears some resemblance to *Goniocora socialis*. It is too much overgrown with Bryozoa to permit examination of the mural costæ, and the septa are only visible when the ends of the corallites are broken off. It has very thick walls, and thin and straight septa. The first cycle of septa extends almost to the centre of the calice, the secondary ones are three fourths the length of the primaries, and the tertiary septa are rudimentary.

The specimen here mentioned was obtained by me at Farley

Down, and the existence of the genus *Goniocora* there establishes its distribution through nearly the whole of the English Oolites. It has now been met with near to the bottom of the Inferior Oolite at Crickley, in the Great Oolite of Farley Down, and in the Coral Rag at Steeple Ashton and other places.

DIMORPHASTRÆA FUNGIFORMIS, n. sp. (Plate V. figs. 22, 23.)

I have obtained from the coral-bed of Combe Down several corals of a species which, as I fail to detect pores in the septa, is here placed in the genus *Dimorphastræa*. It has a pedunculate form with an overhanging rounded fungiform top, the upper surface of which is convex. The peduncular part is short, and the expanded top has a thin and slightly lobed outer edge.

The peduncle has regular and straight costæ, which are similar in size to the septal costæ near the outer part of the corallum, but smaller than those around the central calice.

The central calice is large and prominent, but is centrally depressed, somewhat like the calices of *Crateroseris* and *Adelastræa*. The smaller calices are about twelve in number, and are arranged somewhat symmetrically around the larger one, and, like it, are prominent, with a depressed centre. About one hundred septa enter into the composition of the central calice, and about half the number are observed in the smaller ones. In all the calices the septa anastomose very near to the fossula, but not anywhere else; and none of the septal costæ anastomose, excepting quite at the outer margin of the corallum, and then only sparingly. The septa are rather stout, regular, parallel; and the loculi have the same breadth as the septa themselves. The edges of the septa and the septal costæ have regular and rounded tubercles, much as in *Crateroseris*.

Height of the corallum about 1 inch.

Diameter of the corallum about 1 inch 4 lines.

The present species bears some resemblance to *Dimorphastræa helianthus*, Becker, from the Corallian of Nattheim, in so far as the stoutness of the septa and septal costæ is concerned, but differs wholly from that species in general form, in the shape and arrangement of the calices, and in the absence of anastomosing septal costæ.

At present I am unable to state whether the septa are perforate or not, nor can I speak of the synapticulæ, excepting to say that they are present.

Genus COMOSERIS, d'Orb.

In his recently published "Revision of the Families and Genera of Sclerodermic Zoantharia," Prof. Duncan takes exception to my statement that no very near relationship exists between *Comoseris* and *Oroseris*; and after stating that there is no wall either surrounding the calices or in the collines of the former genus, he asserts that I have "misunderstood the diagnoses of the genera, for it must appear, on reading them, that *Oroseris* can hardly stand as a genus

distinct from *Comoseris. The only distinction is the length of the ridges bounding the calicinal valleys.*" From this concluding statement, which is here printed in italics by me, I feel myself compelled to express a most unqualified dissent. Wishing, however, to make a more critical examination of the ridges of the calicular surface of *Comoseris*, with a view to the determination of the question whether they have walls or not, I have made careful examination of a great many specimens of *Comoseris irradians*, from the Corallian of Steeple Ashton and the Boulonnais, and of *Comoseris vermicularis* from the Great Oolite of the neighbourhood of Bath. The results of this renewed examination I will now proceed to give, premising that the time and trouble will not be wasted which places on a sounder footing our knowledge of the forms now under consideration.

The most superficial observation of well-preserved specimens of *Comoseris irradians* will afford sufficient evidence of the distinctness of the ridges or collines which divide the upper surface of the corallum into segments. When compared with the intervening calicular surface these collines (Pl. V. fig. 24) have a character of their own, quite independently of the calices, and are clothed with costæ, very little resembling the septal costæ in connection with the calices. For instance, on some of the collines the costæ on the one side do not correspond with those on the other side, but alternate with them, just as do the septa of contiguous calices of many compound corals, such as those of some species of *Isastræa*, and they are consequently very suggestive of a concealed wall. Accordingly, in worn specimens a very distinct and continuous line is sometimes observable, simulating a true wall; but sometimes it has a serrated or zigzag course, and then presents so much the appearance of the inflected walls between the lobes of *Phyllogyra* as to suggest a similarity of origin. Without entering further into the question of the nature of the wall observable in the collines of *Comoseris*, I may venture to assert that no such wall, whatever may be its nature, exists in *Oroseris*. To this I shall again refer. I may add, as characteristic of the genus *Comoseris*, that the calices are scattered over the surface between the ridges, and never developed in lines as they commonly are in *Oroseris*. Sometimes the collines are very frequent, and there is only space for one row of calices between them. But when the former widen out, the calices spread out also, and the uniformity of the line is broken. This is very observable in both *Comoseris irradians* and *Comoseris vermicularis* (Pl. V. fig. 25).

Fortunately for the examination of the genus *Oroseris* there is a species commonly occurring in the Great Oolite of Bath, which, when rubbed down, shows the structure of the calices very satisfactorily. In this species the calices are so near together in the lines, and the lines themselves have so much of a radiate direction, that they can only have been the result of direct gemmation from the inner calices outwards, without the interposition of septal costæ. The so-called ridges laterally bounding the lines of calices are really nothing more than ordinary septal costæ, such as are visible between the calices of many species of *Thamnastræa*. The *Thamnastræa*

media of Reuss, from the Cretaceous deposits of Gosau, is a good illustration of this. When the corallum of *Oroseris* has been ground down and polished, the intimate connection of the calices with the costæ forming the supposed ridges becomes even more evident, and the importance of the successive development of the calices in lines still more obvious.

Comoseris vermicularis, M.-Edw. and Haime, Brit. Foss. Cor. p. 122.

Meandrina vermicularis, M'Coy, Ann. & Mag. Nat. Hist. ser. ii. vol. ii. p. 402.

Several very small examples of this species, associated with larger ones, have been met with on Farley Down, which have a very leaf-like form with a thin edge. On these the ridges are especially pronounced, and the costæ, which meet on their line of greater prominence, are rarely continuous.

Oroseris Slatteri, Tomes.

A considerable number of specimens of a species of *Oroseris*, which, though varying extremely in form, may nevertheless be referred to the above species, have been met with at Combe Down, Hampton Down, and Farley Down. Those on Hampton Down are in large blocks of stone, and are of great size, but they are very ill-preserved. The Farley-Down specimens are, however, in a far better condition, and as they occur of all sizes, they furnish a good opportunity of studying the successive periods of growth, and illustrate the particular mode of increase of the genus. Young examples are simple, and usually, but not invariably, turbinate. The calice is circular and not very deep. At this period they greatly resemble *Thecoseris*. At a more advanced stage the calice has become elongate, and it has two or three calices in a line. But it still retains its turbinate form, though it speedily afterwards departs from the upward mode of growth and spreads out in all directions, eventually attaining to a great size and undefinable form.

I am in complete ignorance of the early form and mode of growth of such species of *Oroseris* as are broadly attached or incrusting, but I may venture to record my conviction that none of them exhibit the same method of growth as *Comoseris*.

Genus Tricycloseris, Tomes.

M. Pratz, in his very valuable paper on the Fungidæ, published in the 29th volume of the 'Palæontographica' (1882), suggests that the specimen from which I drew up my description of the genus may be nothing more than a young example of a species appertaining to some other genus. Of the more recently described species from the Great Oolite of Fairford, *Tricycloseris limax*, he entertains the same opinion, and informs me that there are many examples in the museum at Munich which have considerable resemblance to the specimens I have figured. When drawing up the description of *Tricycloseris limax* I made use of many young speci-

mens of *Thamnastræa*, both of Great-Oolite and Inferior-Oolite species, for comparison, but did not in any instance meet with an example having a single row of calices surrounded by long septal costæ. I may confidently state that *Tricycloseris limax* is not the young form of any English species of *Thamnastræa*, though I cannot at present be sure that it is not the young of an *Oroseris*. However, as I know of no species of the latter genus to which it can be referred, I must, for the present at any rate, regard it as a distinct genus, but will omit no opportunity of investigating more fully the several periods of growth of the last-named genus.

MICROSOLENA EXCELSA, M.-Edw. & Haime.

The specimens from which MM. Milne-Edwards and Haime took their description of this species were found in the Great Oolite near Bath, and formed part of Mr. Walton's collection. Some years since I was favoured by that gentleman with specimens from Farley Down, and was at the same time informed by him that all his specimens had been taken from that locality. During the present year (1884) I was conducted to the spot by the Rev. H. H. Winwood, when I made the following note of its occurrence there.

Although fragments may be found scattered all through the coral-bed, it is only at two very restricted and not very distant spots that this species is abundant. It is there found in a softish white layer which is overlain by a bed of hard stone. To the under side of the latter the coral appears to be attached by a rather small base, from which it ramifies in every direction downwards, and forms a thick rounded bush which attains to a height of as much as a foot and a half. The peculiar position of these bush-shaped masses, bottom upwards, would seem to indicate that the whole of the beds had tumbled over and reversed the position of the corals, a conclusion not however borne out by the presence, in place, of the regularly bedded compact Bathstone immediately beneath, which was at one time worked at that place, and is still well exposed.

I have examined several specimens of this species from the railway-cutting near Stonesfield, which are worthy of mention. They are attached to worn specimens of *Thamnastræa Lyelli*, are small in size, and have a pyramidal or subconical form, with a large apical calice, and an irregular ring of smaller ones near the base, just as in the genus *Genabacia*. At this period of their growth they might be referred to an attached species of that genus, such as *Genabacia Sancti-mihieli* of MM. Milne-Edwards and Haime. But other examples of rather more advanced growth have a less regular form, and a greater number of lateral calices, while the earlier-formed ones, near to the terminal calice, have increased visibly in size, and do not differ much in this respect from it. I would suggest the probability of the *Genabacia Sancti-mihieli* being merely the early period of growth of some dendroid species of *Thamnastræa*.

In addition to the foregoing there are several species which are represented by such unsatisfactory specimens that they cannot be

placed even generically. I may allude, however, to one which has a dendroid growth, a thick and wrinkled epitheca, increase by lateral gemmation, and denticulated septa which pass into a central mass which has something the appearance of a papillose columella.

Conclusion.

The beds of massive and nearly unfossiliferous building-stone around Bath indicate a period of continuous deposition which was inconsistent with coralline growth. At the conclusion of this period, when there was a pause, the condition became so far favourable as to be productive of coralline life, and in considerable variety and plenty.

The coral-beds exposed on the Farley and Hampton Downs consist of a whitish mudstone, in which the corals are imbedded, many of them showing, by their incrusting and delicate Bryozoa and Serpulæ, perfect in their details, that they lived and died where they are now found. Such has been the case with some of the tall dendroid examples of *Microsolena excelsa*, which, attaining to a height of a foot and a half, and having a bush-like form, may still be seen in the Farley-Down section attached to the substance on which they grew when the sea of the Great Oolite washed over them. It is probable that the coral-beds of these localities, like other oolitic ones, were not of great extent; for on Combe Down other conditions prevail. The coral-bed there, though holding the same position, presents a very different appearance. The corals are scattered in it in varying degrees of abundance. It is distinctly oolitic, and does not afford the least evidence of having been the place of growth of the corals. On the contrary, they have much the aspect of derived fossils. Yet this bed, from its stratigraphical position, and from the number of corals it contains, is evidently of the same age as those of Farley and Hampton Downs, and may perhaps have been the result of a wash from some near coral-bank.

Correlated with the coralliferous deposits of the Great Oolite of Oxfordshire, those around Bath probably correspond with the one exposed at Caps Lodge, near Burford. At that place, and on Farley Down, are patches of Forest Marble which overlie the coral-beds and appear to hold nearly the same position in relation to them at both those places. Hence the probability of their being on the same geological level.

From the frequency of sponges associated with corals in the Butts Quarry, Hampton Down, and at Farley Down, it is probable that Mr. Moore's sponge-bed at Hampton Rocks is the equivalent of the lower part of the coral-bed, which at that place contains more sponges and fewer corals.

Of the probable age of the coralline deposit in the Lime-kiln Quarry, near Cirencester, I can say nothing.

EXPLANATION OF PLATE V.

Fig. 1. *Barysmilia Etalloni*: the corallum, natural size.
2. —— ——: another specimen, natural size.
3. —— ——: some costæ, magnified, showing their ramification.
4. —— ——: a few costæ, much magnified.
5. *Thamnocœnia oolitica*: the corallum, natural size.
6. —— ——: a part of the corallum, magnified, showing its attachment to a foreign body.
7. —— ——: some of the axillary costæ, magnified.
8. —— ——: a calice, greatly magnified, and one side cut away to show the septa.
9. *Stylosmilia excelsa*: part of a corallum, natural size.
10. —— ——: a portion of the calicular surface, magnified about two diameters.
11. —— ——: a worn calice, considerably magnified.
12. —— ——: an unworn calice, considerably magnified.
13. *Enallohelia socialis*: a portion of the overhanging consolidated upper surface of the corallum, natural size.
14. —— ——: part of a lateral corallite, with a calice, much magnified.
15. *Heliocœnia oolitica*: the corallum, natural size.
16. —— ——: a young calice before becoming prominent.
17. —— ——: a worn calice, showing the lamellar columella.
18. *Stylosmilia reptans*: a young corallum, natural size, attached to a *Thamnastræa*.
19. —— ——: a portion of another specimen, much magnified.
20. —— ——: a worn calice, magnified.
21. —— ——: another calice on the same specimen, having very irregularly developed septa.
22. *Dimorphastræa fungiformis*: the corallum, natural size.
23. —— ——: the calicular surface, natural size.
24. *Comoseris irradians*: portion of a colline of a weathered specimen from Steeple Ashton, magnified, and showing the supposed wall.
25. —— *vermicularis*: portion of a colline of a worn example from the Great Oolite of Farley Down, Bath, magnified.

Discussion.

Dr. Hinde expressed his sense of the value of the researches of Mr. Tomes on the distribution of corals in the Jurassic rocks; but expressed his regret that the specimens described were not laid on the table for the inspection of the Fellows of the Society.

23. SKETCH *of the* GEOLOGY *of* NEW ZEALAND. By Captain F. W. HUTTON, F.G.S., Professor of Biology in the Canterbury College, University of New Zealand. (Read January 14, 1885.)

CONTENTS.

INTRODUCTION.

SIZE for size there are few places in the world where such a variety of geological phenomena are gathered together as in New Zealand. Sedimentary rocks are represented of nearly all ages, from Archæan upwards, and all but the lowest have yielded fossils, in some places abundantly. We have metamorphic and eruptive rocks of nearly all kinds. We have volcanic cones of all sizes, from low hills to Ruapêhu *, more than 9000 feet in height; and we have them in all stages of degradation, from mere stumps to fresh scoria-cones, and one, Tongaríro*, still active. We have also solfataras and mud volcanoes, fumaroles, geysers, and hot springs in abundance. We have a mountain range with an alpine structure, and with glaciers and glacier lakes almost equalling those of Europe. But one thing is missing,—there are no Red Sandstones, either with or without salt and gypsum, and no magnesian limestones. New Zealand appears never to have been the site of great lacustrine deposits. In addition to all these advantages our geographical position is one of great interest. It is in New Zealand alone that we have any record of the ancient floras and faunas that overspread the South Pacific; and it is here we must look for evidence of the changes that have taken place in the physical geography and climate of this enormous area. Situated at the antipodes of Europe, any change of climate, brought about by shifting in position of the earth's axis,

* In all names of Maori origin pronounce the vowels as in Italian.

by changes in the obliquity of the ecliptic, or by any purely cosmical cause whatever, must find its parallel in New Zealand, and, consequently, New Zealand is to Europe a base of verification for all such-like hypotheses.

The geology of New Zealand has been studied for the last twenty-five years, and a great deal is known about it. Valuable memoirs on various detached districts will be found in the 'Quarterly Journal,' in Dr. Hochstetter's works, in the 'Transactions of the New Zealand Institute,' and in the records of the geological surveys of the colony. In the official 'Handbook of New Zealand' (2nd ed., Wellington, 1883), Dr. Hector has given a geological map of the island, and an excellent summary of the distribution of the different formations and their principal fossil contents; but, up to the present, no one has attempted to describe the geology of New Zealand as a whole. I have therefore thought that, as during the last eighteen years I have travelled over the greater part of both the North and South Islands, from the Bay of Islands to Foveaux Straits, it might be useful to offer to the Society a slight sketch of the general geological structure of the country.

For those places which I have not personally examined I have used the observations of others; but in all such cases I have given my authority and a reference to the publication in which it will be found. Several of the opinions expressed are not universally agreed to by other New-Zealand geologists. I merely state my own views, which may be wrong, but which have been arrived at by a long and conscientious study of New-Zealand geology. The chief point of difference between the Survey and myself, I have already discussed in a paper which I have had the honour to submit to the Society*. On this point I have always followed Dr. von Hochstetter, and have never consented to the removal of the Aotéa series and the brown coals of the Waíkato from the Oligocene into the Cretaceo-Tertiary formation of Dr. Hector, where they are grouped with the Saurian beds of the Waípara, and with the Coal-measures of Pákawau, near Nelson. The other points of difference are of minor importance; and I have not thought it advisable to discuss them here, as discussion would be out of place in a mere sketch like the present.

Grouping of the Rocks.

The geology of a district can be studied quite irrespective of any other part of the world. We can group its rocks by means of unconformities (stratigraphical and palæontological) into systems and series, and after having made out its geological history, we can compare it with that of other parts of the world by endeavouring to refer the systems and series to their probable equivalents in Europe. On the other hand, we may commence by trying to refer the rocks of the district to their European equivalents, and refrain from giving names to the local systems. The first plan has been adopted

* "On the Geological Position of the Weka-pass Stone." Read 25th June, 1884, but not yet published.

by Dr. von Haast and by myself; but Dr. Hector prefers the second for the larger groups, giving local names only to the series. Of course there is no real difference between the two methods, it is merely a question of nomenclature; but in a district so far from Europe as is New Zealand, the second plan must for many years be more or less uncertain, and constantly liable to change as our palæontological knowledge increases; and different geologists may call the same group of rocks by different names. The first plan is not open to this objection, and is, indeed, the same as that necessarily employed in Europe. As geological investigation advances, other systems and series may have to be added; but those that are once generally accepted remain for all time.

It is on this first plan, therefore, that I propose to group our rocks; but as the method has as yet been applied only to separate districts, many of the names used are synonymous, and it becomes necessary to introduce a modified scheme applicable to the whole of New Zealand. This I have attempted to do, and will state the considerations that have guided me in drawing it up. In the first place the names of the systems and series should be geographical, and taken from the most typical districts, where the rocks are best developed and contain the most fossils; but names already in pretty general use should not be altered, although some other locality might logically furnish a better name. In the second place the names of the systems and of the series should be of Maori origin, in order that they may be characteristic, and may convey to geologists in all parts of the world the idea that they belong to New Zealand. In the third place, priority in nomenclature should be allowed considerable weight. The following Table shows the arrangement I propose. The right-hand column gives the probable European equivalent, that is the probable age; but it must be understood that this is merely provisional and constantly liable to change. I have introduced among the systems two new names—Hokanúi and Tákaka, each of which represents a natural group of rocks to which no collective name has previously been applied; and yet names are necessary, for in many parts of New Zealand we can refer rocks to one or other of these systems, and yet, in the absence of fossils, it is impossible to say to which series they belong. The grouping of the Tertiary rocks is founded on that given in a former communication to the Society *, but it includes modifications subsequently made.

* "Synopsis of the younger Formations of New Zealand." Quart. Journ. Geol. Soc. vol. xxix. p. 372.

Table of Sedimentary Formations in New Zealand.

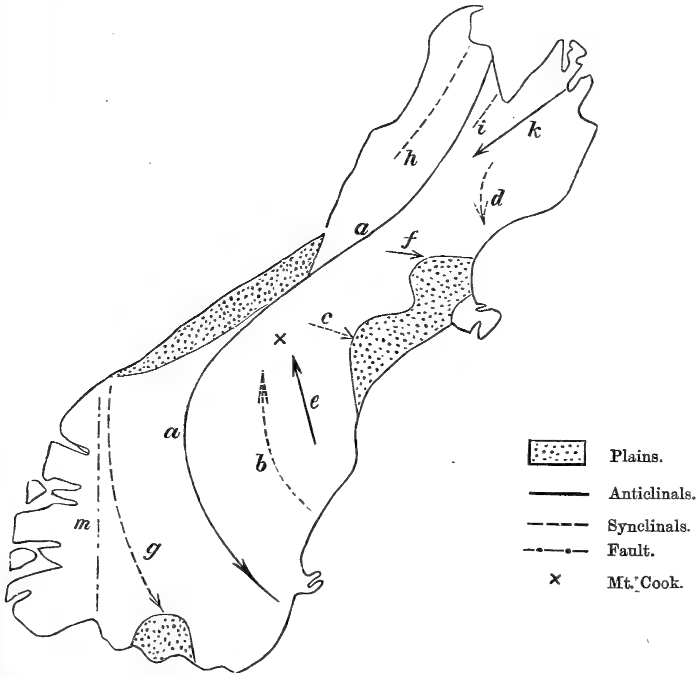
Systems.	Series.	Probable age.
Recent.	Alluvia and Æolian deposits with Moa-bones and traces of Man.	Recent.
Pleistocene.	Raised-beaches and Shore-deposits. Peat-mosses with Moa-bones.	Pleistocene.
Wanganúi System.	Kéreru Series. Ormond Series. Pétane Series. Pútiki Series.	Newer Pliocene.
	Older Glacial deposits. Lignites of Otágo, Mánukau, &c.	Older Pliocene.
Pareóra System.	Awatére Series. Kaníeri Series. Táwhiti Series. Ahuríri Series. Waitemâta Series. Brown Coal of Pomaháka, &c.	Miocene.
Oamarú System.	Mt. Brown Series. Aotéa Series. Otótara Series. Turanganúi Series. Coals of Waíkato, Kaitângata, &c.	Oligocene.
Waípara System.	Amúri Series. Awanúi Series (?). Matakéa Series. Coals of Greymouth, Pákawau, &c.	Upper Cretaceous.
Hokanúi System.	Mataúra Series = Putatáka Series. Flaghill Series. Catlin's River Series. Bastion Series.	Lower Jurassic.
	Wairóa Series. = Otapíri Series. Oréti Series. Kaihíku Series.	Triassic.
Maítai System.	Rimutáka Series. Te Anau Series (?).	Carboniferous.
Tákaka System.	Baton-river Series = Kakanúi Series. Waiháo Series.	Silurian.
	Aorere Series ... Mt. Arthur Series = Wánaka Series.	Ordovician.
Manapoúri System.	Ríwaka Series.	Archæan.

GENERAL GEOLOGICAL STRUCTURE.

In the *South Island* the New-Zealand Alps, dividing Canterbury from Westland, form a narrow range, which rises in Mt. Cook or Aorangi to an altitude of 12,349 feet. To the north and to the

south the mountains bulge out, somewhat in the shape of a dumb-bell, the handle being bordered on the west by the plains of Westland, and on the east by the plains of Canterbury. The southern end of the dumbbell is also notched by the plains of Southland. The mountains are formed by a main anticlinal curve (fig. 1, *a a*) running from the neighbourhood of Lake Wánaka, in Otágo, in a north-easterly direction to Tasman's Bay, and forming the ge-anticlinal of New Zealand. The greater part of the west side of this anticlinal has been removed by denudation in Westland, so that the

Fig. 1.—*The South Island of New Zealand.*



ridge of the Alps no longer coincides with the axis of the curve, but forms part of its south-easterly face. On the Canterbury side the rocks are thrown into three broad synclines (fig. 1, *b*, *c*, *d*), separated by two anticlines (fig. 1, *e*, *f*) running more or less at right angles to the main anticline. The most southerly of these synclines (*b*) goes from the neighbourhood of Palmerston, in Otágo, in a northerly direction to Lake Púkaki; the second (*c*) from the Gawler Downs, in South Canterbury, in a westerly direction to the junction of the Havelock and Clyde rivers, in the Upper Rangitata; the third (*d*) runs from Waiau in a northerly direction to the neighbourhood of the Wairau Gorge, in Nelson Province. The

secondary anticline (e) runs from Hunters Hills, in South Canterbury, northerly to the Two Thumb range, dipping to the north. Mt. Cook is placed at the point where the synclines b and c and the anticline e meet (fig. 1, ×). The anticline f runs from the gorge of the Ashley in a westerly direction. In Otágo the main anticline turns sharply to the south, dipping slightly in that direction, and on its westerly slope a syncline (fig. 1, g) runs from the Greenstone River, west of Lake Wakatipú, through the Hokanúi Mountains to Catlin's River, following with considerable exactness the direction of the Otágo anticline. In the northern part of the South Island the main anticline, turning more to the north, runs out at Tasman's Bay, and is flanked on the north-west by a syncline (h) passing through Snowdon and the Anatoki Mountains to Golden Bay; and on the south-east by another syncline (i) near Nelson, followed by an anticline (k) which runs from the neighbourhood of Top-house in a north-easterly direction through Picton and Queen Charlotte Sounds.

All the sedimentary rocks, up to the Hokanúi System inclusive, partake in these flexures. The Waípara System is also, to some extent, involved in Otágo and Nelson; while the rocks of the Oamarú and younger systems either retain their original plane of deposition or are occasionally locally disturbed. These last occupy, for the most part, valleys, or wrap round spurs of the older rocks. A large fault (fig. 1, m) occurs in the west part of Otágo, running in a nearly north and south direction through Lake Te Anau, and throwing up the Manapoúri System to the west*. No clear evidence of the age of this "Te Anau fault" has as yet been obtained, as the junction between the Manapoúri and Maítai Systems has not been closely studied; but it appears to have been formed before the deposition of the Maítai System.

The *North Island* is very different. A narrow ridge, rising in the Kaimánawa Range, east of Lake Taupo, to 5000 feet or more, runs from Wellington in a north-easterly direction, to near the East Cape, attaining here also, in Hikurangi, a height of 5500 feet. It is bordered on the south-east by hilly country, occasionally attaining nearly to the altitude of the main range, and on the north-west by country which is broken, but generally low, with the exception of three great volcanic cones—Mt. Egmont (8280), Ruapêhu (9195), and Tongaríro (6500)—near the central part of the island. The rocks also differ much from those of the South Island. The crystalline schists of the Tákaka System, which are so conspicuous on the south side of Cook's Straits, suddenly disappear and are quite unknown in the north. The main range is formed by rocks belonging to the Maítai and Hokanúi Systems, smothered on each side by Tertiary beds, through which rise, at intervals, throughout the Auckland Province, isolated ridges and peaks of the older Maítais and Hokanúis.

This sudden change at Cook's Straits strongly suggests the presence of a fault with the upthrow to the south, although it is

* 'Geology of Otago,' p. 23, Dunedin: 1875.

not possible to prove its existence. The rocks of the Oamarú and younger systems are found at nearly equal elevations on both islands; but are higher in the central part of the North Island than elsewhere. On the contrary, the rocks of the Waípara and older systems go to considerably greater heights in the South than in the North Island, consequently the "Cook's Strait fault," if it exists, was probably formed in the interval between the deposition of the Waípara and Oamarú Systems, the downthrow being to the north.

Rocks belonging to the Hokanúi System are found on the eastern side of the Maítais in the Ruahine range in Wellington, and in the Raukamara range near the East Cape. In the Kawhia and Raglan districts, in the Auckland Province, they lie on the western side of the Maítais. So probably the ge-anticlinal of the South Island runs through the centre of the North Island from Wanganúi to the Bay of Plenty.

All the rock systems, up to the Hokanúi inclusive, have much the same lithological characters throughout New Zealand, and can be broken up into series, which are chronologically distinct. They may be called "continental formations," that is, rocks formed on the shore of a continent with large rivers. All the rock systems above the Hokanúis are, on the contrary, very variable in lithological character in different localities, even when not far apart; the only exceptions being a few limestones, probably the relics of coral reefs. These may be considered as "insular formations," that is, as having been deposited round the margin of islands, from which ran no great rivers. It is impossible, at any rate at present, to divide these latter systems into series which are in all cases chronologically distinct. The series here are geographical, and overlap each other; but I have to some extent indicated their probable relations, in the table of formations.

Eruptive rocks cover but a small area in the South Island. Isolated exposures of granite occur along the ge-anticlinal axis from Paringa River in Westland to Lake Rotoiti in Nelson, and in a few other places west of the axis, the largest area being in the south-west of Otágo, at Preservation and Chalky Sounds. On the east there are a few patches of volcanic rocks of younger date. In the North Island, also, volcanic rocks are rare on the east side of the main range; but on the western side, from the centre of the island to Auckland, they cover more than half the country, and appear again in great force further north, between Hokianga and the Bay of Islands. There is no granite in the North Island.

Dr. Hector has estimated the percentage of area covered by these different formations as follows * :—

	North Island.	South Island.
Waîpara System upwards	56·46	24·72
Manapoúri to Hokanúi Systems......	11·92	73·37
Eruptive Rocks	31·62	1·91
	100·00	100·00

* Handbook of New Zealand, 1880. I have altered the arrangement.

Good roofing-slate is found in the Tákaka System in Otágo; statuary marble in the Manapoúri System at Caswell Sound; lithographic limestone, with rocks belonging either to the Waípara or Oamarú Systems, south of Bruce Bay, on the west coast of the South Island. Coal in thin beds is found in the Mataúra Series, but there are no workable seams older than the Matakéa Series at the base of the Waípara System. From the date of the Hokanúi System to the present day land has existed continuously in New Zealand, and no doubt decaying vegetable matter has constantly accumulated in favourable localities. But it was only when these accumulations were covered up by deposition that they have been preserved. This occurred in two ways:—(1) By marine deposits on subsidence of the land; and (2) by lacustrine and fluviatile deposits. Consequently we find coals or lignites at the base of the Waípara, Oamarú, Pareóra, and Wanganúi Systems covered by marine beds; and also we have coals and lignites of intermediate age covered by fresh-water beds. These latter, however, we may for convenience group in each case in the system to which the overlying series belongs, although there may be an unconformity between them. The New-Zealand coals, therefore, belong to what I have called insular formations. They do not form large basins, as in England, N. America, or Australia, but occur wrapping round hills formed by older rocks, and are consequently almost always worked by day-levels and not by shafts.

Descriptive Geology.

Manapoúri System.

This system is largely developed on the west coast of Otágo, from Preservation Inlet to Milford Sound, extending inland to Lake Te Anau. Elsewhere it is only known on the west side of Tasman's Bay in Nelson, from Motueka to Separation Point (Ríwaka series); but it may probably occur in Westland also.

The rocks consist of grey and red gneiss, garnet-bearing schist, hornblende-schist, mica-schist, quartz-schist, and occasionally granular limestone. Scales of graphite have been found in the mica-schist at Dusky Sound. The beds are not contorted, and the dip is almost constantly westerly, varying from 45° to 80°, the only easterly dip recorded being at the marble quarries on the north side of Caswell Sound *; and here this dip seems to be local, for the marble on the south side of the Sound dips S.W., 45°. We can only escape from the conclusion that these rocks have a thickness of many miles by supposing either that the plane of foliation does not always coincide with the original plane of bedding, or that a series of reverse folds occur, neither of which has as yet been proved.

Tákaka System.

This system covers a large extent of country in Collingwood County, and can be traced south, continuously through Mt. Arthur,

* McKay, Reports of Geological Survey, 1881, p. 115.

Merino Mts., Lyell Mts., Brunner Mts., Victoria Mts., Werner Mts., and along the westerly base of the New Zealand Alps into Otágo, where it again expands considerably, and turning eastward with the anticlinal axis, covers the greater part of the interior of that province, reaching the sea in the neighbourhood of Dunedin. The centre of the secondary anticlinal fold in S. Canterbury (fig. 1, *e*) and the one in Marlborough (*k*) are also occupied by these rocks.

In the north-west part of the Nelson Province, the Tákaka System can be divided into three series, all of which appear to be conformable. The lowest of these is the *Mt. Arthur Series*, which consists principally of crystalline limestone with bituminous and micaceous schists. This series has yielded to Mr. A. McKay, the indefatigable assistant of the Geological Survey, a few Crinoids and a Coral. The middle or *Aorere Series* is formed principally by blue slates, but also contains sandstones as well as felspathic and quartzose schists. In the slates, Mr. J. L. Morley and Mr. S. H. Cox have collected Graptolites, some of which appear to be identical with Australian Ordovician forms. The upper or *Baton-River Series* consists of calcareous slates and argillaceous limestones with slates and sandstones. The following list of the "more important or abundant" fossils of this series is given by Mr. McKay *:—

Calymene Blumenbachii.	Rhynchonella Wilsoni.
Homalonotus Knightii.	Stricklandia lyrata.
Orthoceras.	Atrypa reticularis.
Murchisonia terebralis.	Orthis.
Avicula lamnoniensis.	Strophomena corrugatella.
Pterinea spinosa.	Chonetes striatella.
Spirifera radiata.	

It also contains many corals and corallines.

Fossils of the Baton-river Series have been found as far south as Reefton, and in addition *Spirifera vespertilio* and *Homalonotus expansus*, Hector †; but beyond that the metamorphism gets more pronounced, and the rocks of the system pass altogether at the base into chlorite-schist and quartzose mica-schist, with occasional beds of graphite (Wánaka Series), and in the upper parts into phyllites with clay-slate and quartzite (Kakanúi Series). No calcareous rocks are known in the south.

The thickness of this system in Otágo cannot, I think, be less than 100,000 feet; but in the Nelson Province Dr. Hector estimates it at from 15,000 to 18,000 feet only.

The junction of the Tákaka with the underlying Manapoúri System can be studied in the Ríwaka Mountains, west of Tasman's Bay, and here Mr. S. H. Cox has shown a complete unconformity between the two ‡ (fig. 2, *b* and *c*).

* Reports of Geological Survey, 1878-9, p. 126.
† Trans. N. Z. Institute, vol. ix. p. 602 (1877).
‡ Reports of Geological Survey, 1879–80, p. 2, Section A.A.

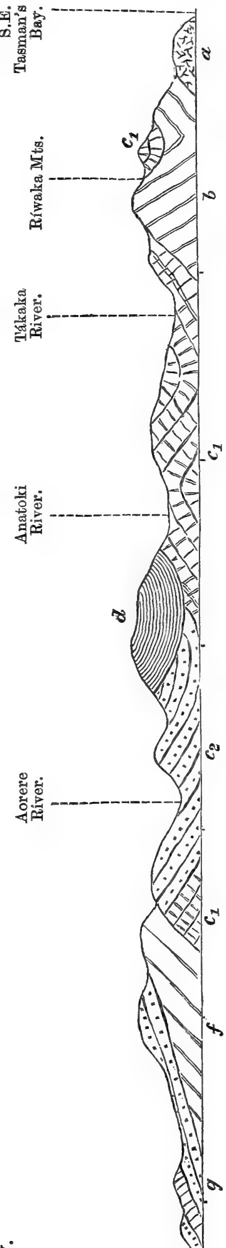


Fig. 2.—*Diagrammatic Section from the West Coast of New Zealand to Tasman's Bay.* (Distance 40 miles.)

a. Granite. *b.* Manapoúri System (Ríwaka Series). *c.* Tákaka System (c_1. Mt. Arthur Series; c_2. Aorere Series).
d. Maítai System. *f.* Waípara System. *g.* Oamarú System.

It is very remarkable that in the Province of Nelson, where there are several exposures of granite in connection with this system, and where the rocks are, in places, violently disturbed, metamorphic action has been much less than in Otágo, where the rocks lie nearly flat and no granitic areas occur. This militates much against Mr. Mallet's idea that the heat of metamorphism is due to crushing. On the other hand, the enormous thickness of the system in Otágo and the gradual decrease of metamorphic action upward make it probable that, in this case, the metamorphism is due to the internal heat of the earth.

Maítai System.

This system is found in the *South Island*, flanking the Tákaka System on both sides of the main anticlinal (*a*, fig. 1), except in Westland, where it has been almost entirely removed. In the *North Island* it forms the chief part of the main range from Wellington to East Cape (Rimutáka Series), as well as most of the outcrops of old sedimentary rocks in the Province of Auckland. The rocks are chiefly argillites, red and black slates, and grey and green sandstones, with occasional beds of limestone in the South Island. Thick masses of greenstone-ash are found interbedded with the slates and sandstones in many places in New Zealand, but these rocks appear to be local.

The thickness is estimated by Dr. Hector at from 7,000 to 10,000 feet; but it is very difficult to form an opinion, as the stratification is often obscure.

That an unconformity exists between this and the Tákaka System

is evident. In Nelson it has been shown to rest indifferently on the Aorere and the Mt. Arthur Series *, the Baton-river Series being absent (fig. 2, *d*). In Westland, Mr. Cox describes these rocks as quite unconformable to the schists †; and at Reefton they have been shown to be unconformable to the Baton-river Series (= Reefton Series) by Dr. Hector, Mr. Cox, and Mr. McKay. At the Tapanúi Mts. in Otágo, the system rests partly on the Wánaka, and partly on the Kakanúi Series, while in the West-coast Sounds it appears to rest upon the Manapoúri System. But notwithstanding this unconformity, it is by no means easy to draw the line between this and the Tákaka System in Otágo; for the metamorphic action has passed upwards through both, assimilating to some extent along the boundary the rocks of each system.

In consequence of the rocks being generally unfossiliferous, it has not yet been found possible to break up this system into distinct series. According to Dr. Hector, the following fossils occur in limestone at the Dun Mountain, near the base of the system :—*Spirifera bisulcata*, *Spirifera glabra*, *Productus brachythærus*, *Cyathophyllum* and *Cyathocrinus*. In the upper part of the system the only fossils known are the tubes of two or more species of Tubicolous Annelides, perhaps *Cornulites* ‡.

The *Rimutáka Series* of the North Island no doubt belongs to the Maítai System. The *Te Anau Series* of Dr. Hector is now considered by the Geological Survey as forming the base of the Maítai System, but formerly it was placed at the base of the Hokanúi System §. It is said to consist of "an enormous thickness of greenstone breccias, aphanite slates, and diorite sandstones, with great contemporaneous floes and dykes of diorite, serpentine, syenites, and felsite" ‖; and it appears to me to be merely the igneous rocks belonging to the system, and not to represent any particular horizon. I say this, however, with much hesitation, because Mr. S. H. Cox, to whose opinion I attach great weight, differs from me on this point and agrees with Dr. Hector.

Remarkable beds of manganese ore, generally associated with red jasperoid slates, are found in several places in the Auckland Province and also near Wellington. In many respects these rocks remind one of the deposits now being formed in the deeper parts of the Atlantic and Pacific Oceans, and the absence of fossils strengthens the impresssion.

This system is the same as my "Kaikoura formation." The "Westland formation," and the lower part of the "Mount Torlesse formation" of Dr. von Haast also belong to it. The rocks called "Maítai slates" by Dr. von Hochstetter are seen in the neighbourhood of Nelson to overlie rocks containing *Monotis* belonging to the Wairóa Series; and in addition to this, Dr. Hector collected from

* Cox, Reports Geological Survey, 1881, p. 47. Up. Devonian, *a*.
† Reports Geological Survey, 1874–76, p. 68, and sections.
‡ See McKay, Rep. Geol. Surv. 1879–80, p. 90.
§ Reports of Geological Survey, 1876–7, p. v.
‖ 'Handbook of New Zealand,' 1883, p. 36.

them, in 1866, fossils which were said to be *Inoceramus* *. For these reasons I have, in my report on the Geology of Otágo (1875), associated Dr. Hochstetter's Maítai slates with the Wairóa Series; and Dr. Hector in 1877 considered them to be the same as the Kaihíku Series of the Nuggets and Mt. Potts †. But on the other hand these slates resemble in lithological character those found in other parts of New Zealand underlying the Hokanúi System; and there is therefore some doubt as to the true position of the Maítai slates. Consequently I should have preferred to retain my name of "Kaikoura" for this system; but the term Maítai has been largely used by the Officers of the Survey for the present group of rocks, and I do not wish to destroy this approach to uniformity by insisting on the desirability of employing some other name. I am the more ready to do so, as I think it probable that the superior position of the Maítai slates to the Wairóa Series near Nelson may be due to inversion ‡, and that the supposed *Inoceramus* may belong to some other genus of the same family.

Hokanúi System.

This system is found in the *North Island* between Kawhia and the Waíkato, and again at Port Waíkato (Putatáka Series) §. It also occurs at Wellington, in the Ruahine range, and again in the Raukamára range, near the East Cape. In the *South Island* it is found on the eastern side of the ge-anticline, outside the Maítai rocks, and occupies part of the synclines, *b*, *c*, and *d*, already mentioned (fig. 1), as well as the Southland syncline (*g*). In Westland and in the north-west of the Nelson Province it is quite unknown. A small patch is found near Nelson (Wairóa Series), but the two largest areas covered by this system are on the north-east and on the south of the island. Commencing in the neighbourhood of Kaikoura peninsula, it skirts the main range to the Hanmer plains, sending northwards a long tongue towards the Wairau gorge. To the south it reaches the Canterbury Plains at the gorge of the Ashley. It reappears in the Malvern Hills, and in the north branch of the river Ashburton, whence it runs southwards to the neighbourhood of Mt. Peel, extending inland through the Clent Hills and Rangitáta River as far as the junction of the Clyde and the Havelock, near Mt. Potts. Another exposure of these rocks occurs somewhere near the Mackenzie Plains, in the centre of the basin formed by the main anticline and its easterly extension in Otágo (*a*, *a*, fig. 1), and the secondary anticline (*e*) running from Hunters Hills towards Mt. Cook. Mr. A. McKay has proved the existence of this exposure by finding fossils be-

* Reports of Geological Survey, 1870–1, p. 113, and 1878–9, p. 117.

† Rep. Geol. Survey, 1876–7, p. v.

‡ McKay, Rep. Geol. Survey, 1877–8, pp. 155–158.

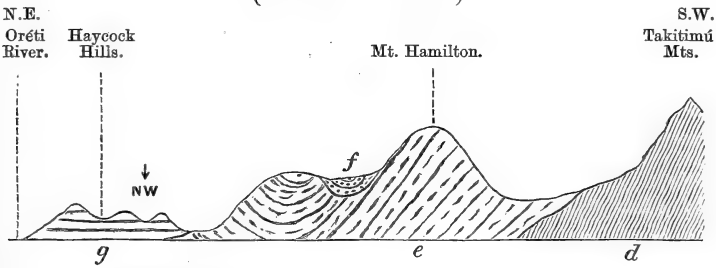
§ Rocks of this age were said by Dr. Hector to occur north of Auckland, near Mahurangi (Geol. Rep. 1874–6, p. vi), and doubtfully at the island of Kawau (Geol. Rep. 1868–9, p. 45); but this has not been confirmed by Mr. Cox (Geol. Rep. 1879–80, p. 14).

longing to the system in boulders in the Waítaki *; but the rocks have not yet been detected *in situ*. The southern development of the system is on the coast between the rivers Clutha and Mataúra, passing inland through the Hokanúi Mountains to beyond Mt. Hamilton. This is the best locality for making out the series of rocks forming the system, a work which has been ably accomplished by Mr. S. H. Cox †.

The rocks are principally blue slates and green or brown sandstones, with beds of conglomerate sometimes passing into breccias. There are no limestones. In the lower series beds of greenstone ash occur, and in the upper thin seams of coal. It is a littoral formation, plant-remains being found throughout. The thickness has been estimated both by Mr. Cox and by myself at between 20,000 and 25,000 feet in Southland.

This system is undoubtedly unconformable to the Maítai System, but it not easy to get good sections to prove this. The best is perhaps in Southland, at the Takitimú Mts., where I reported an

Fig. 3.—*Section from Oreti River to the Takitimú Mountains.* (Distance 12 miles.)



d. Maítai System.
e. Hokanúi System.
f. Waípara System.
g. Oamarú System.

unconformity in 1872 ‡, and this has since been confirmed by Mr. Cox § (fig. 3, *e*). In no place, however, is it known to rest on the Maítai System.

The Hokanúi System forms the upper part of Dr. von Haast's "Mt. Torlesse formation." It has been divided into a considerable number of series, all conformable to each other, but distinguished by their fossils. The fossils, however, have not been described; and, although it may very probably be true that all these series will be found to be necessary, at present it is impossible to recognize them in the field, and it therefore seems to me preferable to reduce the series to three at the most. The *Kaihíku Series* forms the base of the system; but fossils are rare, and I doubt much whether it can

* Reports of Geological Survey, 1881, p. 77.
† Rep. Geol. Surv. 1877–8, p. 25.
‡ Rep. Geol. Surv. 1871–2, p. 103.
§ Rep. Geol. Surv. 1877–8, p. 113.

be separated from the Wairóa Series. The only characteristic fossil mentioned by Dr. Hector is *Trigonotreta undulata.* Labyrinthodont teeth and *Glossopteris* are found both here and in the next higher series. Remains of what appears to be an *Ichthyosaurus* * have been found near Mt. Potts, in S. Canterbury, in beds recognized by the Geological Survey as belonging to the Kaihíku Series. Dr. Hector considers this series of Permian age; at the same time he notices the absence of "the usual Palæozoic elements of a Permian fauna," and, I may add, of a Permian flora also.

The *Wairóa Series* is well characterized by the following:—

Belemnites (?) otapiriensis, *Hector.*
Monotis salinaria, *var.* richmondiana, *Zittel.*
Halobia Lommelli, *Wissm.*
Mytilus problematicus, *Zittel.*
Spirigera Wreyi, *Suess.*

There are also several Spirifers which are referred by Dr. Hector to new genera or subgenera (not yet described) called *Clavigera, Rastelligera,* and *Psioidea* †.

Among the plants are *Dammara fossilis* (Ung.), *Zamites, Rhachophyllum, Glossopteris,* and *Neuropteris.*

The *Mataúra Series* is characterized by

Ammonites novo-zelandicus, *Hauer.*
Belemnites aucklandicus, *Hauer.*
—— Hochstetteri, *Hector* ‡.
Belemnites catlinensis, *Hector.*
Inoceramus Haasti, *Hochst.*
Aucella plicata, *Zittel.*

The plants are *Polypodium Hochstetteri,* Ung., *Asplenium palæopteris,* Ung., *Tæniopteris linearis,* and *Macrotæniopteris lata* §.

Waípara System.

In the *South Island* this system extends, with a few interruptions, from Cape Campbell in Cook's Straits to the river Ashburton in S. Canterbury (Amúri Series), and an isolated patch occurs in the Trelissick basin on the upper Waimakariri. In Otágo it includes the coal-measures of Shag-point and the Horse Range (Matakéa Series), as also the coal of Mt. Hamilton and possibly a small patch on the north shore of Lake Wakatipu. In the Nelson Province it includes the coal-measures of Pákawau, and the bituminous coals of the Buller and Greymouth. In the *North Island* Mr. McKay has recognized the system on the east coast of Wellington ‖, and it apparently covers a large extent of country in the Waiapu district, in which oil-springs are situated (Awanúi Series); and again on the Wairóa river north of Kaipara Harbour ¶ in Auckland. But

* *Ichthyosaurus australis,* Hector, Trans. N. Z. Institute, vi. p. 355.

† Dr. Hector also mentions *Nautilus mesodiscus, Nautilus goniatites, Pleurotomaria ornata,* and *Tancredia truncata.*

‡ Trans. N. Z. Institute, vol. x. p. 486.

§ Dr. Hector also mentions *Trigonia costata, Spiriferina rostrata, Epithyris, Cycadites, Echinostrobus,* and *Camptopteris.*

‖ Reports of Geological Survey, 1878–9, p. 79.

¶ Cox, Reports of Geological Survey, 1879–80, p. 22.

until the fossils from these North-Island localities have been carefully compared with those from the typical districts at Amúri and Waípara in the South Island, it is impossible to feel quite certain about their age.

The thickness of the system at Amúri Bluff is estimated by Mr. M^{c}Kay at about 1600 feet. I considered the Matakéa Series at Shag Point to be between 6000 and 7000 feet. The strata are usually much disturbed except in North Canterbury. In Marlborough they go, in Benmore, to an altitude of 4360 feet. In Buller county they form mountains 5000 or 6000 feet high, and at Mt. Hamilton in Otágo they occur at an elevation of 3700 feet. In the North Island the greatest elevation of the system is in the East Cape district, and perhaps does not exceed 2000 feet.

This system is quite unconformable to the Hokanúi System in Marlborough and Canterbury. The coal-measures of the Malvern Hills and of Mt. Hamilton (fig. 3, *f*) rest on the Hokanúi System; those of Shag Point, the Grey, and the Buller, rest on the Maítai System; and those of Pákawau in Nelson on the Tákaka System, showing a complete stratigraphical unconformity. The palæontological break is probably equally great, but it has not yet been proved.

The upper part of the system in Marlborough and Canterbury consists of white argillaceous limestone (Amúri limestone) often containing flints. Dr. Hector calls it a deep-sea deposit; but it must have been formed within a few miles of land, and in the Kaikoura peninsula has thin bands of fine conglomerate running through it. Near Oxford, in Canterbury, a chalky limestone occurs which, according to Dr. Hector, is "made up chiefly of minute shells of Foraminifera" *, but I can find none in it. Although it is remarkably pure, it must have been formed close to land, as the Oxford Hills behind it rise to a considerable height. It is no doubt the remains of an old coral reef; but as no fossils have been found in it, it is uncertain whether it belongs here or to the Oamarú System.

In the typical district remains of marine Saurians belonging to the genera *Plesiosaurus*, *Mauisaurus*, *Taniwhasaurus*, *Polycotyles*, and *Leiodon* have been found and have been described by Sir R. Owen † and by Dr. Hector ‡. Among the Mollusca are *Belemnites australis*, Phillips §, *Conchothyra parasitica*, M^{c}Coy ‖, a genus allied to *Pugnellus*, Conrad, of the North-American Cretaceous, *Inoceramus*, *Trigonia sulcata*, Hector ¶, and many others not yet described. The plants found at the base of the system at Waípara are chiefly dicotyledonous angiosperms and *Dammara*. From Pákawau Dr. Hochstetter obtained *Equisetites*, *Neuropteris*, and either *Zamites* or *Phœnicites*; but leaves of dicotyledonous angio-

* Reports of Geological Survey, 1879–80, p. viii.
† Brit. Assoc. Rep. 1861, p. 122, and Geol. Mag. 1870.
‡ Trans. N. Z. Institute, vol. vi. p. 333.
§ Hector, Trans. N. Z. Inst. x. p. 487.
‖ See Reports of Geological Survey, 1873–4, p. 37, footnote.
¶ Trans. N. Z. Inst. vi. p. 358, footnote.

sperms also occur there *. The reptilian remains occur above the beds with dicotyledonous leaves at the Waípara, and they occur above the beds with *Belemnites australis* at Amúri Bluff; but the relation of the Belemnite beds to the leaf-beds has not yet been made out. Mr. A. McKay reports having found *Ammonites* at the Ten-mile Creek near Greymouth †, and also near Waimirima, between Cape Kidnappers and Cape Turnagain on the east coast of Wellington ‡. He also mentions finding a skeleton, apparently reptilian, at Lake Wakatipú, from which "fragments of a jaw with long slender Plesiosaurus-like teeth" were obtained §. In the Otágo Museum there is a fragment of an Ammonite from the Matakéa Series near Shag Point ||. Dr. Hector mentions *Inoceramus* and *Belemnites* from the Awanúi Series in the East Cape District ¶; and Mr. Cox reports *Inoceramus* from the Wairóa river, Kaípara Harbour **. A "smooth *Inoceramus*" is also mentioned by Mr. McKay as occurring in many places between East Cape and Cape Palliser ††.

No undoubted Mesozoic fossils have been reported from any other of the districts considered by the Geological Survey as "Cretaceo-tertiary." According to Dr. Hector "no trace of a Belemnite possessing the upper part of its guard or phragmocone has been discovered in any bed above the black grit" ‡‡, that is about the middle of the Amúri Series. But, he says, smooth fusiform bodies, with a minute depression or perforation at the lower end, which exfoliate from the central portion of the guard of *B. australis*, have been found at Green Island, near Dunedin, at Waitaki, and at Mt. Hamilton in Otágo. He further says that these bodies form the *Acanthocomax* (? *Actinocamax*) of Miller, and have frequently been mistaken for spines of *Cidaris*. But as no whole guard of a Belemnite, even without the phragmocone, has as yet been found at any of these localities, nor in any rock supposed to be of the same age, the nature of this fossil must, for the present, be considered doubtful. The rocks in which it occurs at Green Island and at the Waítaki, I consider, from other palæontological evidence, to belong to the Oamarú System. This fossil is identical with the "pseudo-belemnite" described by Dr. Mantell from what are known as the "Hutchinson Quarry beds" at Oamarú §§, and which are considered by the Geological Survey to be of Upper Eocene age.

Oamarú System.

In the *North Island* this system occurs in many places north of Auckland and all down the west coast from Port Waíkato to Mokau

* Reports of Geological Survey, 1870–1, p. 157.
† Rep. Geol. Surv. 1873–4, p. 81. ‡ Rep. Geol. Surv. 1874–6, p. 45.
§ Rep. Geol. Surv. 1879–80, p. 145. || Geology of Otago, p. 45.
¶ Rep. Geol. Surv. 1873–4, p. xviii.
** Rep. Geol. Surv. 1879–80, p. 22. †† Rep. Geol. Surv. 1877–8, p. 22.
‡‡ Trans. N. Z. Institute, vol. x. p. 489.
§§ Quart. Journ. Geol. Soc. vi. p. 329. The Ototara limestone of Mr. Mantell included the Hutchinson Quarry beds with abundant shells and corals, as well as the Oamarú building-stone.

(Aotéa Series). On the east coast it appears to be largely developed in the northern part of Hawke's Bay, extending inland to Lake Waikaremoana *, and eastward to Poverty Bay (Turanganúi Series); but the fossils require more examination before the proper position of this series can be ascertained. In the Wellington Province it has only been recognized in the neighbourhood of Cape Palliser †. Valuable seams of coal lie conformably below marine sandstones belonging to this system at the Bay of Islands, and at Whangarei. The coal-beds of Drury and the Waíkato underlie the system unconformably, but they probably belong to it ‡.

In the *South Island* it occurs at Tákaka and Tata Island in Golden Bay, and extends down the west coast for some distance from Cape Farewell; it is found again from Cape Foulwind to Greymouth. On the east side of the island, commencing at Cook's Straits, it occurs at intervals along the eastern flanks of the mountains all through Marlborough, Canterbury, Otágo, and Southland to the Waiau river. Some of the inland valleys on both sides of the Alps are also partly filled with rocks belonging to this system. Valuable seams of brown coal are found at Dunedin, Tokomairíro, Kaitangáta, and Nightcap Hills in Southland. In Nelson Province the brown coals of West Wanganúi probably belong here, as also may much of the brown coal up the Buller river.

I have, in another communication to the Society §, given my reasons for thinking that this system is unconformable to the Waípara System in the northern part of Canterbury. No well-defined junction is found in Otágo; but both at the Horse Ranges and at Mt. Hamilton (fig. 3, *f* and *g*), the general geological structure of the country leaves no doubt that the two are also unconformable there ‖. There is no published section showing the relation between the two systems at Greymouth. The system attains an elevation of about 4000 feet in the North Island, east of Lake Waikaremoana. In the South Island it probably never exceeds 2500 feet.

Remains of Cetaceans have been found at Caversham ¶, near Dunedin, at Weka Pass, and many other places. A Zeuglodont (*Kekenodon onemata*, Hector **) has been found at the Waítaki. A gigantic penguin (*Palæeudyptes antarcticus*, Huxley ††), occurs at Oamarú in the Ototara building-stone; a splendid specimen from here is in the Otágo Museum; also at the Curiosity Shop on the Rakaia River, at Trelissick Basin, at Amúri Bluff, and near Brighton on the west coast ‡‡. A crab (*Harpactocarcinus tumidus*, H. Wood-

* Cox, Reports of Geological Survey, 1874–6, p. 102.

† McKay, Rep. Geol. Surv. 1878–9, p. 80.

‡ Trans. N. Z. Institute, iii. p. 244.

§ "On the Geological Relations of the Weka-pass Stone."

‖ Geology of Otago, p. 50.

¶ Including a skull in the Otago Museum.

** Trans. N. Z. Institute, vol. xiii. p. 435.

†† Ann. Nat. Hist. ser. 3, vol. iii. p. 509; and Quart. Journ. Geol. Soc. xv. p. 670 (1859).

‡‡ Hector, Trans. N. Z. Inst. iv. p. 341.

ward), originally obtained by Mr. McKay near Brighton*, has also been found in greensands at Wharekauri in the Waítaki †.

Of the Mollusca, the most interesting are *Aturia ziczac*, Sow., var. *australis*, McCoy, *Mitra*, *Marginella*, *Struthiolaria senex*, Hutton, and *Pholadomya*. About 9 or 10 per cent. of the species appear to be recent. The Echinodermata have been considered to have a Cretaceous facies, and this is to some extent true if they are compared with European forms; but it is not true if the comparison be made, as it ought to be, with the Australian Echinodermata.

The occurrence of Nummulites has been reported in the North Island from Waipu ‡, Lower Waíkato §, Poverty Bay and the East Cape district ||, and from the east coast of Wellington ¶. In the South Island, from the Greymouth district **, and between Westport and Cape Foulwind ††. But I doubt much if any true Nummulite has ever been found in New Zealand. At any rate I have never seen one, although I have been shown the so-called Nummulites in the Wellington Museum.

Unger has described in the 'Reise der Novara,' several leaves belonging to the genera *Fagus*, *Loranthophyllum*, *Myrtifolium*, and *Phyllites*, brought by Dr. von Hochstetter from Drury and Waíkato. In the same publication, Dr. Zittel has described Mollusca and Echinodermata from Papakura, Waíkato South Head, Motupípi, and Cape Farewell, all of which belong to this system. The Foraminifera of Raglan (=Waingaróa) are described by Dr. Stache. Other Bryozoa, Foraminifera, and Entomostraca from the Ototara Limestone are mentioned by Dr. Mantell ‡‡, and some corals and Bryozoa are described by the Rev. Tenison-Woods §§.

The following are the most characteristic fossils:—

Pleurotoma hebes, *Hutton* || ||.
Struthiolaria senex, *Hutton*.
Scalaria Browni, *Zittel*.
—— rotunda, *Hutton*.
Dentalium tenue, *Hutton*.
Panopæa plicata, *Hutton*.
Pecten Williamsoni, *Zittel*.
—— Fischeri, *Zittel*.
—— Hutchinsoni, *Hutton*.
—— athleta, *Zittel*.
Lima lævigata, *Hutton*.
—— palæata, *Hutton*.
Lovenia formosa (*Zittel*).
Macropneustes spatangiformis, *Hutton*.
Meoma Crawfordi, *Hutton*.
Schizaster rotundatus, *Zittel*.
Isis dactyla, *Tenison-Woods*.
Flabellum laticostatum, *Tenison-Woods*.

Pecten Hochstetteri, Zittel, and *P. Zittelli*, Hutton, are also characteristic, but they both pass up into the Pareóra System.

* Reports of Geological Survey, 1873–74, p. 111.
† McKay, Rep. Geol. Surv. 1881, p. 74.
‡ Rep. Geol. Surv. 1874–76, p. vi.
§ Rep. Geol. Surv. 1876–77, p. 21.
|| Rep. Geol. Surv. 1873–74, p. 116, &c.
¶ Rep. Geol. Surv. 1874–76, p. 47.
** Rep. Geol. Surv. 1873–74, p. xiv.
†† Rep. Geol. Surv. 1873–74, p. 106.
‡‡ Quart. Journ. Geol. Soc. vi. p. 329 (1850).
§§ Palæontology of New Zealand, pt. iv. Wellington, 1880.
|| || For descriptions see 'Catalogue of the Tertiary Mollusca and Echinodermata of New Zealand,' Wellington, 1873. The plates mentioned in the preface are not yet published.

Pareóra System.

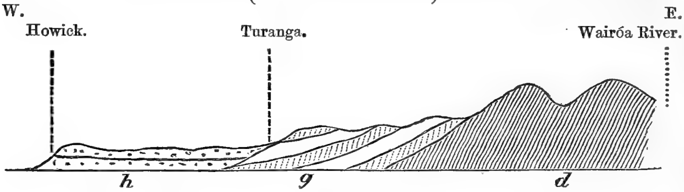
In the *North Island* this system is widely distributed in the north from Cape Rodney, Kawau, and Kaipara Harbour to Auckland, where it forms the cliffs round Waitemáta Harbour, and at Orakei Bay (Waitemáta Series); and extends south to the Waíkato. Its only other occurrence on the west coast is at the White Cliffs in Taranáki. On the east coast it covers a large district between East Cape and Poverty Bay (Táwhiti Series); and commencing again at Napier, it is largely developed all down the coast to Cook's Straits (Ahuríri Series). In the centre of the island it is found in the upper parts of the Rangitiki, Wanganúi, and Waitotára Rivers. In the *South Island* it is found on the west coast at Nelson (the cliffs), and from Reefton to Hokítika (Kaníeri Series). It is much better developed on the east coast; in the Awatére valley in Marlborough (Awatére Series), between the Hurinúi and Waípara rivers, in the Trelissick basin, and again in S. Canterbury and Otágo from the Rangitata to Moëraki. A few patches occur in S. Otágo and in Southland, and it is extensively developed on the east side of Lake Te Anau. It also occurs at the Chatham Islands.

In the South Island the upper part of the system is often formed by thick beds of gravel. This is best seen near Nelson, where, in the Port Hills, gravels are distinctly interbedded with sandstone containing Pareóra fossils; and these gravels, sometimes cemented into conglomerates, pass inland to Lake Rotoiti, attaining, in the Moutére and Wai-iti hills, an elevation of 2334 feet *. The same may be seen in the railway-cutting on the north side of Weka Pass in Canterbury.

This system attains, in the South Island, an elevation of 3000 feet at Mt. Pleasant, near Lake Te Anau, and also in several valleys in the centre of the New-Zealand Alps. In the North Island it goes to 4000 feet between Napier and the Mohaka River. The rocks, although thrown into rolling curves, are not violently disturbed except locally, and especially in the neighbourhood of volcanic rocks. There is a remarkable instance in the cliffs near Auckland. This section is hard to understand, but it is quite clear. The Pareóra System has been shown by myself † and by Mr. Cox ‡, to lie quite unconformably on the Oamarú System in the Auckland Province (fig. 4, *h* and *g*). In the East-Cape district, Dr. Hector and Mr. McKay show it unconformable to the Turanganúi Series §. In N. Canterbury no unconformity has been made out. In S. Canterbury Dr. von Haast reports unconformity between the two ||, and in Otágo the unconformity is usually well marked ¶.

* Reports of Geological Survey, 1873–74, p. 49.
† Trans. N. Z. Inst. iii. p. 244. ‡ Rep. Geol. Surv. 1879–80, p. 17.
§ Rep. Geol. Surv. 1873–74, sections.
|| Geology of Canterbury and Westland, p. 318.
¶ Geology of Otago, p. 58.

Fig. 4.—*Section from near Howick, Auckland, to the Wairóa River.* (Distance 8 miles.)



d. Maítai System. *g.* Oamarú System. *h.* Pareóra System.

The humerus of a Porpoise (*Phocœnopsis Mantelli*, Huxley *) was found by Mr. Mantell at Awamóa, near Oamarú. He also found a fragment of a bird's bone, 1½ inch in diameter, in a septarium from Hampden (= Onekakára) †, and this, from its size, must have belonged to a Moa. Teeth of the huge Miocene shark, *Carcharodon megalodon*, Owen, have been found near East Cape. But the system is chiefly characterized by its numerous species of *Struthiolaria*. The other interesting Mollusca are *Polytropa*, *Siphonalia*, *Cominella*, *Turbinella*, *Ancillaria*, *Conus*, *Sigaretus*, *Xenophora*, *Rotella*, *Monodonta*, *Crassatella*, *Perna*, *Trigonia*, *Limopsis*, and *Solenella*. Large species of *Cucullœa*, *Cardium spatiosum*, and *Turbo superbus* suggest a sea warmer than at present; but with these lived several species which are now found as far south as Foveaux Straits,—e.g. *Voluta pacifica*, *Triton Spengleri*, *Venus Stutchburyi*, and *Pectunculus laticostatus*. From 20 to 45 per cent. of the species of Mollusca and Brachiopoda are recent. Fossil plants of the system are numerous near Tapanúi in Otágo. Dr. Zittel has described several Mollusca from Cape Rodney, Napier, cliffs near Nelson, and the Awatére Valley. Dr. Stoliczka has described the Bryozoa, and F. Karrer the Foraminifera from Orakei Bay.

The following may be considered as characteristic:—

Cominella Robinsoni (*Zittel*).
Voluta corrugata, *Hutton*.
Pleurotoma sulcata, *Hutton*.
Conus Trailli, *Hutton*.
Natica solida, *Sow*.
Struthiolaria cincta, *Hutton*.
—— tuberculata, *Hutton*.
Dentalium Mantelli, *Zittel*.
—— læve, *Hutton*.
—— solidum, *Hutton*.
Cardium spatiosum, *Hutton*.
Crassatella ampla, *Zittel*.
Limopsis insolita, *Sow*.
Pecten secta, *Hutton*.
—— Triphooki, *Zittel*.
—— accrementa, *Hutton*.
Ostrea ingens, *Zittel*.
Flabellum corbicula, *Ten.-Woods*.
Platyhelia distans, *Ten.-Woods*.

Pectunculus globosus, Hutton, and *Ostrea nelsoniana*, Zittel, may also be considered as characteristic, but they occur as well in the Oamarú System. Indeed these two systems are closely connected palæontologically, and the following highly characteristic species occur equally in both, but do not occur outside, these systems:—

* Quart. Journ. Geol. Soc. xv. p. 670; and Ann. Nat. Hist. ser. 3, vol. iii. p. 509.

† Quart. Journ. Geol. Soc. vi. p. 326.

Turritella gigantea, *Hutton.*
Scalaria lyrata, *Zittel.*
Dentalium giganteum, *Sow.*
Cucullæa alta, *Sow.*
Pecten Burnetti, *Zittel.*
—— polymorphoides, *Zittel.*
Ostrea Wüllerstorfi, *Zittel.*

Wanganúi System.

Marine beds belonging to this system have been proved by palæontological evidence only in the southern half of North Island, from Patea and Wanganúi on Cook's Straits (Pútiki Series), to the Ngaruroro River (Kéreru Series), and Esk River (Pétane Series) in Hawkes Bay. There can be no doubt, however, that the system also occurs at Poverty Bay (Ormond Series), at Taranáki, round Mánukau Harbour, on the west side of Whangarei Harbour, and in various other places in the province of Auckland. In the South Island the marine beds of the north appear to be represented by thick unfossiliferous gravels, which are very difficult to distinguish from the upper gravels of the Pareóra System. These beds rest unconformably on the Pareóra System in the western part of Wellington Province *, and also in Hawkes Bay †, wherever the junction has been seen, the only doubtful place being at Pohui, east of Napier, where, according to Mr. Cox ‡, the unconformity mentioned by Mr. Percy Smith below his "Pohui papá §" does not exist. The marine beds attain an elevation of more than 2000 feet near Napier.

I have elsewhere ‖ given reasons for concluding that the former great extension of our glaciers was caused by greater elevation of the land during the interval between the Pareóra System and the marine beds of the Wanganúi System. As these marine beds are fossiliferous in the North Island only, where there are no traces of former glaciation, it is not possible to get direct proof of this; but in Otágo the old Taieri moraine, between Lake Waihola and the sea, which forms low rounded hills between 400 and 500 feet in height, is, on the seaward side, covered nearly to the top by marine gravels, which may belong to this system or may be younger.

The fossils of this system are very different from those of the last. We miss the species of *Struthiolaria* and *Pecten*; and there is no *Conus* or *Limopsis*. On the other hand *Murex*, *Trophon*, *Pisania*, and *Cassis* appear for the first time. It is also remarkable that there should be three genera, *Oliva*, *Sigaretus*, and *Risella*, not now represented in our seas. From 70 to 90 per cent. of the Mollusca, and all the Brachiopoda are recent. Dr. von Haast has found Moa bones in morainic deposits ¶ belonging to this system. A list of some of the Foraminifera from the Pétane Series by Mr. G. R. Vine, junior, will be found in the 'Transactions of the New Zealand Institute,' vol. xiii. p. 393. In addition to the large percentage of recent species, this system may be recognized by:—

* McKay, Rep. Geol. Surv. 1877–78, p. 19; and *l.c.* 1878–79, p. 84.
† McKay, *l.c.* 1878–79.
‡ Rep. Geol. Surv. 1874–76, p. 97.
§ Trans. N. Z. Inst. ix. p. 568.
‖ Trans. N. Z. Inst. v. p. 384, and Geology of Otago, p. 83.
¶ Geology of Canterbury and Westland, p. 380, and Quart. Journ. Geol. Soc. xxi. p. 135.

Trophon expansus, *Hutton*.
Pisania Drewii, *Hutton*.
Pleurotoma wanganuiensis, *Hutton*.
—— tuberculata, *Kirk*.
Galerus inflatus, *Hutton*.
Trochus conicus, *Hutton*.
Zizyphinus Hodgei, *Hutton*.
Dentalium nanum, *Hutton*.
Cytherea assimilis, *Hutton*.
Ostrea corrugata, *Hutton*.
Trochocyathus quinarius, *Ten.-Woods*.
Flabellum rugulosum, *Ten.-Woods*.

There are also many others, the descriptions of which are not yet published.

Pleistocene Period.

Raised Beaches.—At the mouth of the River Thames, near Auckland, there is a raised beach some 10 or 12 feet in height containing marine shells *, and at the North Head of Mánukau Harbour a well-cut beach-terrace is seen at about the same altitude †.

Below the town of Tauranga there is a raised beach about 25 feet above the sea. Beach-terraces are plainly seen at Hick's Bay near the East Cape; but I have never landed to examine them. At Taranáki Dr. Hector has described Pleistocene deposits with recent marine shells at 150 feet above the sea ‡. Beach-terraces occur also near Wellington; and Mr. McKay describes them as much more than 200 feet high near Cape Palliser, in Cook's Straits §. On the west coast of the South Island Dr. Hector mentions comparatively recent beach-terraces extending to more than 220 feet above the sea ||, and Mr. Dobson has estimated these terraces at 400 feet ¶. At Amúri Bluff there are three terraces, and Mr. McKay obtained recent marine shells from the highest, which, he says, is 500 feet above the sea**. These three terraces are also seen a little further south, at the mouth of the river Conway. At Motannau, in N. Canterbury, a raised beach with marine shells goes to a height of 150 feet above the sea. A deposit of fine silt occurs along the east coast of Canterbury and Otágo from Banks's Peninsula to Moëraki. At its base it is stratified, frequently with layers of gravel, but its upper portions are unstratified. At Timarú it contains a few marine shells ††. At Oamarú the gravels at its base contain large numbers of recent marine shells ‡‡, and the upper parts have yielded Moa-bones, and the skull of a large Sea-Elephant (*Morunga elephantina*). This silt goes to a height of 800 feet in Banks's Peninsula §§, and to 500 or 600 feet at Oamarú ||||. Also the entrance to the West-coast Sounds are terraced to an estimated height of 800 feet.

If we plot these heights and distances to scale it appears

* Rep. Geol. Surv. 1868–69, p. 22.
† Trans. N. Z. Inst. ii. p. 161.
‡ Rep. Geol. Surv. 1866–7, p. 3.
§ Rep. Geol. Surv. 1878–9, p. 84.
|| Rep. Geol. Surv. 1866–7, p. 29.
¶ Trans. N. Z. Inst. vii. p. 444.
** Rep. Geol. Surv. 1874–6, p. 177.
†† McKay, Rep. Geol. Surv. 1876–7, p. 49.
‡‡ Geology of Otago, p. 70.
§§ Haast, Trans. N. Z. Inst. vi. p. 423.
|||| The marine origin of this deposit is, however, disputed. Dr. von Haast considers it to be land löss. See Geol. Canterbury, p. 367, and Trans. N. Z. Inst. xv. p. 411.

as if the rise were tolerably regular from Auckland to Banks's Peninsula; but we must remember that the observations are still very imperfect; indeed I believe that the sea stood much higher than 800 feet in Canterbury *. The remarkable river-terraces found throughout the South Island and the southern and central portions of the North Island furnish collateral proof of elevation. They do not occur in the north part of New Zealand, where also there are no raised beaches.

Peat-mosses.—Several ancient peat-mosses have been examined in the South Island, such as those of Waikouaiti and Hamilton in Otágo, and Glenmark in Canterbury. They appear to be very similar in character, and I take the one at Hamilton as an example, as I explored it myself †. This was a small dry basin, about 50 feet in diameter and from 5 to 6 feet deep in the deepest part, excavated out of a bed of clay. This small basin was filled with peat and bones inextricably mixed and forming a compact layer from two to four feet thick, and before being disturbed its surface was rather higher than the surrounding country, which was quite flat for a distance of 200 yards. Out of the small hole there were taken about 7 tons weight of Moa-bones, more than half of them quite rotten, the remains of at least 400 birds ‡. A great quantity of quartz gravel occurred among the bones, some of the stones going up to one or two pounds, and one piece of rock weighed between 10 and 12 pounds. Probably this bog was but the remains of a much larger one. Besides Moa-bones there were found abundant remains of *Cnemiornis*, and a few bones of *Harpagornis* and *Apteryx*, as well as a number of small birds not yet determined: also several bones of *Sphenodon punctatum*. The bones were not waterworn, neither were they broken. I collected from the peat the following land- and fresh-water shells:—*Thalassia obnubila*, Reeve, and *Limnæa leptosoma*, Hutton. The former is now common near Dunedin, but requires damp bush to live in. The latter is not now known in the South Island, but is found near Wellington.

Diluvial Epoch.—The Mollusca of the north of New Zealand differ sufficiently from those of the south to make any migration which might take place in either direction easily distinguishable §. But neither in the Wanganúi System nor in the raised beaches is there any trace of a northerly migration. Neither are there any signs of a Pleistocene glaciation of New Zealand greater than at present. Consequently there is no evidence to show that the high eccentricity of the earth's orbit that prevailed in Pleistocene times produced a Glacial epoch here. But there are several facts which appear to support the view that this high eccentricity produced a diluvial epoch by causing greater winter snowfall and greater summer floods.

* Trans. N. Z. Inst. xvi. p. 449.

† See Booth in Trans. N. Z. Inst. vii. p. 123.

‡ Dr. von Haast thinks that at least 1000 birds were imbedded in the Glenmark bog.

§ Trans. N. Z. Inst. viii. p. 383.

In the first place the occurrence of the bones of *Apteryx*, as well as those of the water-loving *Sphenodon* and the land shell *Thalassia obnubila*, with bones of the Moa at Hamilton, prove that the dry, treeless, interior region of Otágo was at that time covered with forest; and this is corroborated by some of the trunks of the trees themselves still lying on the sides of the mountains. Secondly the extraordinary agglomeration of Moa-bones in the peat-mosses at Glenmark, Hamilton, and other localities, where hardly even two toe-bones were found in their proper places, can only be accounted for by supposing that heavy floods swept these bones up and deposited them in the low ground. And thirdly, the silt of Northern Otágo and Canterbury, usually unfossiliferous but sometimes containing Moa-bones and only stratified at its base, seems to imply heavy and often recurring floods washing away the fine mud left by the retreat of the glaciers during subsidence and its rapid deposition in the sea.

Recent Period.

It is only in æolian or fluviatile deposits of this age that we find traces of man. Sand dunes are well developed in many places round the coasts of New Zealand. Between Mánukau Harbour and Port Waíkato they form hills 500 or 600 feet in height, the sands being often cemented into hard rock by iron-oxide derived from the black iron-sand.

A very complete list of the localities where Moa-bones have been found, whether in peat-mosses, sand-dunes, or caves, has been given by Mr. C. Smith *, to which I can add nothing of importance. No less than eighteen species of *Dinornis* have been found, all of which have been described, more or less fully, by Sir R. Owen. Of these, five are recorded from the North Island only, and nine from the South Island only; while four are common to both islands. The following table shows their distribution. I have divided them into four subgenera.

Distribution of the Species of Dinornis.

Subgenus.	North Island.	Both Islands.	South Island.
MOVIA (Reichenbach).	D. giganteus. D. gracilis.	D. ingens. D. struthioides.	D. maximus. D. altus. D. robustus.
SYORNIS (Reichenbach).	D. didiformis.	D. casuarinus. D. dromioides.	D. rheides. D. Huttonii.
PALAPTERYX (Owen).			D. elephantopus. D. crassus. D. gravis.
CELA (Reichenbach).	D. geranoides. D. curtus.		D. pygmæus.

* Geological Magazine, ser. 3, vol. i. p. 129 (1884).

Eruptive Rocks.

The oldest of our eruptive rocks are found in the *Manapoúri System* at the West-Coast Sounds, in the form of dykes of white granite, minette, eurite, &c. They do not penetrate any higher, and no eruptive rocks have yet been noticed belonging to the *Tákaka System*.

Maítai System.—The pink granite found at Preservation Inlet, as well as the granites along the ge-anticlinal axis through Westland and Nelson, have penetrated some of the rocks of the Maítai System, but are found as rolled fragments in the rocks of the Kaihíku Series at the base of the Hokanúi System*. Their eruption therefore must have taken place some time during the deposition of the Maítai System, and they are probably contemporaneous with the dykes of syenite, diorite, olivine rocks, and serpentines as well as the greenstone ashes found in various localities in the Maítai System.

Hokanúi System.—There is evidence of eruptive rocks belonging to this date near the Hurinúi Plains, where the river Mandamus cuts through a volcanic region in which ash-beds and lava-streams are interbedded with slates containing remains of plants †.

Waípara System.—In the South Island extensive eruptions of white or light-coloured quartz-rhyolites and dolerites, the latter now often altered into melaphyres, took place along the western margin of the Canterbury plains at the Malvern Hills, Alford Forest, Mt. Somers, and Gawler Downs, during the deposition of the older rocks belonging to this system ‡. Quartz-rhyolites of the same character form the base of the western portion of Banks's Peninsula, but the rest of this volcanic system is of later date. On the west coast of the South Island basic volcanic rocks occur at Paringa and other places south of Bruce Bay, which may belong to the Waípara System or to the next §. In the North Island volcanic rocks, said to be of this age, occur on the east coast of Wellington, at Red Island, south of Cape Kidnappers ||, and perhaps near Castle Point ¶.

Oamarú System.—In the South Island basaltic rocks are interbedded with sedimentary rocks of this system at Oamarú Cape**; at Culverden, and at Pahau†† on the north side of the Hurinúi Plains. In the Trelissick basin on the Waimakaríri, beds of volcanic tuff overlie and underlie a limestone considered to be the equivalent of the Ototara stone‡‡. At Limestone Bluff and at the Two Brothers, on the south branch of the River Ashburton, a "Palagonite tuff" §§

* Cox, Rep. Geol. Surv. 1877–78, p. 47.

† Haast, Rep. Geol. Surv. 1870–71, p. 46, and Hutton, Rep. Geol. Surv. 1873–74, p. 34.

‡ Haast, Rep. Geol. Surv. 1871–72, p. 12, and *l. c.* 1873–74, p. 7; Hutton, Rep. Geol. Surv. 1873–74, p. 40; Daintree, Trans. N. Z. Institute, vii. p 458.

§ Cox, Rep. Geol. Surv. 1874–76, p. 8; Haast, Geol. Canterbury, p. 302.

|| McKay, Rep. Geol. Surv. 1874–76, p. 45.

¶ McKay, *l. c.* 1874–76, p. 59.

** Geology of Otago, p. 55.

†† Rep. Geol. Surv. 1873–74, p. 46.

‡‡ McKay, Rep. Geol. Surv. 1879-80, p. 60.

§§ Haast, Geology of Canterbury, p. 313.

occurs, which, while agreeing well in ultimate analysis with specimens obtained in other countries, does not contain any palagonite visible to the naked eye.

The andesites and trachytes forming the centre of the Dunedin volcanic system are interbedded in the peninsula with sedimentary rocks, probably of this age; but the later eruptions of basaltic rocks which surround the andesites may belong to the Pareóra System*.

According to Dr. von Haast, the results of whose extensive researches on the structure of Banks's Peninsula† I can in great part confirm, there have been here, in addition to the quartz-rhyolites of the Waípara System already mentioned, three periods of activity. To the first of these belong the caldera of Lyttelton, Little River, and Akaróa, in which the lava-flows are chiefly augite-andesites ‡ and occasionally trachytes. The dykes are chiefly trachytes, but occasionally augite-andesites, and at least one is rhyolite §. To the second period belong Mt. Herbert and Mt. Sinclair, which are formed of andesites, but without any visible dykes. To the third period belongs only Quail Island in Lyttelton Harbour, also composed of andesites with dykes of trachyte (?). The first and second of these periods of eruption are quite evident, and both appear to have been entirely subaerial in character. There does not, however, seem to be any means of distinguishing the third from the second period, and it is comparatively insignificant. The quartz-rhyolites had suffered severely from denudation, and thick beds of sandstone had been formed by their disintegration, before the more basic eruptions took place; consequently we may consider these latter as younger than the Waípara System. On the other hand the whole have suffered too much from denudation to allow us to put any of them later than the Pareóra System; and as both periods of eruption were subaerial, we have the interval between the Waípara and Oamarú Systems or that between the Oamarú and Pareóra Systems to choose between. I think it probable that the calderas of Lyttelton and Akaróa belong to the Oamarú System, but Mt. Herbert may belong to the Pareóra System.

In the North Island the trachytes (?) of Hick's Bay, near the East Cape, are distinctly overlain by beds of the Táwhiti Series ‖, and they may therefore belong to the Oamarú System.

Pareóra System.—In the South Island basalts and basaltic tuffs are interbedded with rocks of this system at Mt. Cookson, north of the Hurinúi plains. The basalts of Moëraki Peninsula are clearly seen to overlie a Pareóra clay (the Onekakára clay of Mantell ¶), and as they have undergone great denudation, we cannot put them into the Wanganúi System. The volcanic rocks of Timarú may also

* Geology of Otago, p. 55.

† Geology of Canterbury and Westland, p. 324, and Trans. N. Z. Institute, xi. p. 495.

‡ For the knowledge that these rocks are andesites I am indebted to Prof. G. H. F. Ulrich, who has examined them microscopically.

§ Ulrich.

‖ Cox, Rep. Geol. Surv. 1876–77, p. 112.

¶ Geology of Otago, p. 61.

perhaps be placed here. No trace of a scoria-cone nor of a tuff-crater exists anywhere in the South Island; all the volcanic rocks, even Banks's Peninsula, which is 3000 feet high, appear to have suffered from marine denudation.

In the North Island volcanic ash beds and andesitic breccias are found associated with the Waitemáta Series near Auckland; and the trachytes (?) of Whangarei, the Great Barrier Island, and Coromandel are no doubt of the same age. Fossil wood of *Podocarpium dacrydioides*, Ung., was obtained by Dr. Hochstetter from the trachyte tuffs of both the Great Barrier and Coromandel; and from the much decomposed basaltic rocks behind Drury he obtained wood of *Nicolia zelandica*, Ung., which was also found in the Pareóra gravels of Moutere Hills near Nelson. On the Great Barrier Island the trachytic cone of Ahumáta, 1500 feet high, still retains a well-marked tuff crater *, as also does Arid Island †.

The andesites ‡, and gold-bearing propylites (?) of the Thames may be of the same age, or they may possibly date back to the Oamarú System; but we have no evidence that any andesites in New Zealand are older than the Oamarú System §. A piece of carbonized wood impregnated with iron pyrites, but showing plainly annual rings of growth, was obtained from the gold-bearing propylites in the "Maid of England" claim ‖.

Wanganúi System.—There is no trace of volcanic action having taken place in the South Island during this period or later; but in the North Island, on the western side of the main range, volcanic eruptions on a large scale occurred from the commencement of the Pareóra and are even now not quite over. At Mt. Egmont in Taranaki the first eruptions, perhaps of Pareóra date, were trachytes containing (according to Zirkel) both sanidine and oligoclase, and are much like some of the rocks of Banks's Peninsula. These were succeeded by dolerites and basalts. The bases of Ruapêhu and of Tongaríro also appear to consist of trachytes, but here the later eruptions have been dark-coloured rhyolites and pumice. These siliceous eruptions appear to have commenced during the formation of the upper part of the Wanganúi System (Keréru Series), for no pumice occurs in the lower beds. Rhyolites are extensively developed round Lake Taupo, and in the Hot-spring district. In the valley of the Thames it appears that they are of later date than the dolerites (? augite-andesites) of Cape Colville peninsula ¶. Around Auckland and at the Bay of Islands basalts were the only lavas erupted.

* Rep. Geol. Surv. 1868–69, p. 6.

† Trans. N. Z. Inst. i. p. 164, new ed. p. 108.

‡ I am indebted to Prof. Ulrich for the information that the rocks called by me dolerites, in Rep. Geol. Surv. 1868–69, p. 20, are typical augite-andesites According to Dr. Hector they contain olivine (Geol. Rep. 1868–69, p. 42, no. ix.); I saw none myself.

§ See "On the Geological Structure of the Thames Goldfields," in Trans. N. Z. Inst. vi. p. 272; and Cox, Rep. Geol. Surv. 1882, p 4.

‖ Rep. Geol. Surv. 1868–69, p. 44.

¶ Cox, Rep. Geol. Surv. 1883, p. 20.

In the neighbourhood of Auckland many scoria-cones with well-preserved craters occur at very slight elevations above the sea. These are younger than the clays belonging to the Wanganúi System round Mánukau Harbour, and have never undergone marine denudation; but some of the tuff-craters, such as Lake Pupuki on the north shore, are of submarine origin.

Obsidian occurs in many places and is particularly plentiful on Mayor Island in the Bay of Plenty. Perlite is found in the Hot-springs district; and a finely laminated rhyolite, called lithoidite by Richthofen, is found at Totara on the east shore of Lake Taupo *. Tachylyte occurs but rarely. We have no glassy basaltic lava-streams, as in the Sandwich Islands and Friendly Islands. Leucite has been found in a basalt of uncertain age near Castle Point on the east coast of Wellington †. Anorthite occurs in the volcanic rocks of Campbell Island ‡, but the age of these also is unknown. The only active volcano in New Zealand is Tongaríro, and its eruptions are feeble. White Island, in the Bay of Plenty, appears to be in the solfatara stage. It has never been known in eruption, and there is no appearance of recent lava-streams §.

Two interesting sections of volcanoes occur in the sea-cliffs of the North Island. I described the one on the west coast, between Port Waíkato and Raglan, some years ago ‖. The other, which is situated at the west head of Támaki River, near Auckland, I have the late Mr. Heaphy's authority for saying is the same as the one figured by him ¶, and copied into the works of Scrope and Judd**. This is the only crater near Auckland that is cut completely through by a sea cliff; and I quite agree with Dr. Hochstetter that it is a tuff-crater only, without any lava-stream ††.

Distribution of Volcanic Rocks in the North Island.

I have already pointed out that, judging from the relative position of the Maítai and Hokanúi Systems, it is probable that the ge-anticlinal of New Zealand passes through the centre of the North Island from Wanganúi to the Bay of Plenty. If now we draw a line parallel to this axis from Mt. Egmont, through the Karioi at Raglan, and on to Mercury Bay in the Coromandel peninsula, we find that to the north-west of this line the intermediate rocks have been followed by basic rocks (none of which are known south-east of the line) without any acidic rocks. On the ge-anticlinal itself, from Ruapêhu to the Bay of Plenty, the intermediate rocks are followed by acidic rocks without any traces of basic rocks. To the east of the axis basic rocks occur again on the east coast of

* Hochstetter, 'Reise der Novara,' Geol. i. p. 113.
† Colonial-Museum Laboratory Reports, x. p. 48.
‡ Filhol, Comptes Rendus, Feb. 1882.
§ Edwin, Trans. N. Z. Inst. i. p. 57 (new ed. p. 463); Hector, Trans. N. Z. Inst. iii. p. 278.
‖ Quart. Journ. Geol. Soc. xxv. p. 13.
¶ Quart. Journ. Geol. Soc. xvi. p. 242.
** Volcanoes, p. 165, f. 66.
†† 'Reise der Novara,' Geology, i. p. 176, no. 28, and Map.

Wellington; but these are thought to be older. I have mentioned that a line of granite exposures occurs along the ge-anticlinal axis in the South Island, from Paringa to Separation Point in Nelson; and the question naturally suggests itself, Are these rhyolites of the North Island derived from a northerly extension of the granite zone of the South Island? It seems possible that granitic rocks may be nearer the surface here than they are in the northern parts of the province of Auckland, and this may account for the eruption of rhyolites only in the centre of the North Island. They may be merely a *réchauffée* of Maítai granites of the northern part of the ge-anticlinal.

Hot Springs.

In the South Island hot springs are known only in two places, one in the Hanmer plains, Amúri county, and the other near Lake Sumner, about 40 miles S.W. of the first. In the North Island there is only one hot spring east of the main range; it is near Waiapu, in the East Cape district. But west of the main range they are very numerous; all the more important ones lie in a broad band along the axis of the ge-anticlinal, from the base of Tongaríro, through Lake Taupo and the upper Waíkato, to Lake Rotomahána and Lake Rotorua, forming one of the most wonderful regions in the world. Dr. Hochstetter distinguishes three parallel lines of springs; but it requires some determination in the tracing of lines to make this out. North of this region the hot springs are isolated. They occur at Pupunúi on the Thames, near Lake Whangape in the Lower Waíkato, at Waiwera near Auckland, at Mahurangi, also near the Bay of Islands, and on the Great Barrier Island. Geysers, solfataras, fumaroles, mud-volcanoes, and springs depositing siliceous sinter are confined to the central rhyolitic region of the North Island.

The best description of the hot-spring region will be found in Dr. Hochstetter's works. The Rev. R. Abbay has given a very clear explanation of the formation of our sinter terraces *. Accounts of the mineral waters have been given by Mr. Skey † and by Dr. Hector ‡.

Minerals.

An exhaustive list of all the minerals hitherto found in New Zealand has been given by Mr. S. H. Cox §. Among the more interesting are platiridium, osmium-iridium, hessite, sapphire, spinel ruby, emerald, tridymite, nephrite, and kyanite. No diamond has as yet been found, A curious jet-like mineral occurs in veins, or lining veins, in sandstones belonging to the Wanganúi System at One-tree Point, on the west side of Whangarei Harbour ||. Gold occurs in the Tákaka System and in the Maítai System, where

* Quart. Journ. Geol. Soc. xxxiv. p. 170. For an account of the shape of the basin and pipe of Te Tarata, see Trans. N. Z. Inst. i. p. 162 (new ed. p. 106).

† Trans. N. Z. Inst. x. p. 243.

‡ Handbook of New Zealand, 1883.

§ Trans. N. Z. Inst. vols. xiv., xv., and xvi.

|| Trans. N. Z. Inst. iii. p. 250.

penetrated by Plutonic rocks. It is also found, with several other metals, in the Tertiary andesites and propylites of the Thames, in the province of Auckland. Native mercury and cinnabar are being deposited at the present time by hot springs near the Bay of Islands *. Silver, copper, antimony, lead, and zinc have been found in several places, and hæmatite occurs in abundance at Parapara, near Nelson, in rocks belonging to the Tákaka System, as well as in many other localities.

Discussion.

Mr. Redman called attention to some beaches on the east coast of New Zealand, and discussed their mode of formation. One, the "Ninety-mile" Beach, is really 140 miles long. The southern leeward drift is resultant from north winds prevailing as two to one over south winds.

* Trans. N. Z. Institute, iii. p. 252.

24. *On the* Granitic *and* Schistose Rocks *of* Northern Donegal.

By C. Callaway, Esq., D.Sc., F.G.S. (Read March 11, 1885.)

Contents.

In my paper * on "The Age of the Newer Gneissic Rocks of the Northern Highlands," I suggested that a study of the old rocks of Ireland would probably aid in connecting the Scottish types with those of South Britain; and, in the summer of 1884, I visited the north of Ireland to ascertain how far my suspicion was justified by the facts. As Professor Hull had announced the discovery of Laurentian gneiss in the same area, I included the relations between this group and the schists in my investigation. A continuance of stormy weather prevented the completion of my plans; but I obtained satisfactory proof of the nature and relations of the chief granitoid mass, and collected partial material for the study of the schistose rocks. As the result of a month's work, I came to the conclusion that the schistose rocks of Northern Donegal were separable into two groups, and that the so-called "Laurentian" was merely a mass of granite intrusive in the older of them.

The President (Professor Bonney), with his usual kindness, has examined fifty-five microscopic sections of Irish rocks, and he permits me to use at my discretion the rough notes which he has furnished. It is to be regretted that pressure of other work has prevented him from undertaking a more elaborate investigation.

* Quart. Journ. Geol. Soc. Aug. 1883, p. 355.

I. The Granite.

1. State of previous Opinion.

Mr. R. H. Scott, F.R.S.*, claims a metamorphic origin for this rock.

Mr. E. H. Blake † takes the same view.

In a subsequent paper ‡ Mr. Scott offers a theory of the origin of the granite. He considers that all the rocks of the region were originally stratified, but that, by subsequent metamorphism, some of the beds were altered into granite, some into gneiss, and some into other kinds of rocks, without much altering the relative positions of the strata.

The Rev. Dr. Haughton, F.R.S.§, regarded the granites as "being stratified and not intrusive, and therefore varying considerably in different localities according to the beds from which they have been formed by the metamorphic action."

Professor Hull ‖ accepts the metamorphic theory of the granite, but regards it as of "Laurentian" age; and the schists which follow it on the east and west are referred by him to the "Lower Silurian," the structure of the district being, in his view, on the type of the Highlands of the north-west of Scotland. This writer agrees with previous observers that the granite "contains beds of crystalline limestone," and that it is "foliated and bedded;" and he adds that "the upper beds which occur along the south-eastern margin are largely interstratified with hornblendic and micaceous schists."

2. The Granite Promontory.

The granite appears in several patches in Donegal. The chief area is a squarish mass sending off from its north-eastern corner an arm or promontory, about fourteen miles in length, and in breadth tapering from six miles to three. The arm strikes nearly north-east. Disappearing under the schist near Glen, the granite reappears in Dunaff Head, and again in Malin Head. These outlying patches are precisely on the north-easterly prolongation of the strike of the promontory. There is distinct foliation in the promontory; but I am not aware of any in the main mass or in the outlying patches to the north-east. This promontory will therefore receive our chief attention.

3. Relations between the Granite and the adjacent Schists.

The evidence for the sedimentary origin of the granite adduced by Prof. Hull, agreeing, as it did, with the observations of previous observers, left me in little doubt that I should find the old gneiss in

* Journ. Geol. Soc. Dubl. vol. ix. p. 285. † *Ibid.* p. 295.

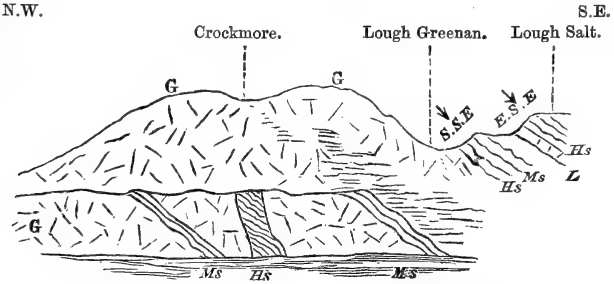
‡ Report Brit. Assoc. 1861.

§ Quoted in the 'Memoirs of the Geological Survey of Ireland' (105 and 114, p. 9).

‖ Trans. Roy. Dubl. Soc. ser. 2, vol. i. (1882).

Donegal. The revelation made by the rocks themselves was both a surprise and a disappointment. I have visited Prof. Hull's most critical sections, and some districts not described by him.

Fig. 1.—*Section in Barnesbeg Gap and on Lough Greenan.*



G. Granite. *Ms.* Mica-schist.
L. Limestone. *Hs.* Hornblende-schist.

Section in Barnesbeg Gap (fig. 1, north-west end).

It was in this wild ravine, near a wooden barrack erected for a body of soldiers appointed to protect a cottage opposite, that I first touched the granite. The rock surfaces on each side were well rounded by ice-action, and the colouring and weathering suggested some bits of Hebridean scenery in Scotland. The first blow of the hammer destroyed my preconceptions. The rock was grey in colour, uniform in texture, consisting of a well-crystallized, coarse-grained aggregate of quartz, black mica, and felspar, mostly orthoclase. There were no signs of bedding, and, but for a roughly linear arrangement of the mica, I should have declared I had before me as typical a granite as I had ever seen.

Towards the junction with the schists at the south-eastern end of the Gap, the granite grows lighter in colour and less coarse in grain. At the entrance of the gorge we reach the important part of the section. Masses of schist lie between masses of granite, and at a hasty glance the two appear to be interstratified. I first came upon a thin band of well-crystallized mica-schist, dipping at a moderate angle to the south-east, with granite on both sides of it. A little further on, I reached hornblende-schist, the hornblende (consisting of small black sparkling crystals) predominating over the quartz. This rock at first was rather puzzling. It had no regular dip, but rose vertically like a dyke, with irregular sides, as if it had thickened abruptly downwards. But this diorite-like mass was distinctly foliated, and I at first thought that I had before me a case of pressure-foliation in an igneous rock. The foliation, however, was not parallel to either of the margins of the mass or at right angles to the direction of the thrust which had contorted the region, but sloped at a medium angle to the south-east, in accordance with the prevailing dip of the schists outside the granite.

Grey orthoclase granite appeared on the other side of this schist, and fifty yards further on I came to a second mass of hornblende-schist, succeeded by several others separated from each other by granite, which sometimes penetrated the schists in veins. The granite between the fragments of schists was similar to the variety at the barrack, but was less coarse, and a linear arrangement of the mica was not apparent in it. The last rock seen in this traverse was a glistening mica-schist, which seemed to lie outside the granite.

From this examination it appeared to me perfectly clear that I was on the margin of a mass of intrusive granite. This rock, homogeneous in texture and composition, lay between irregular fragments of schist, which displayed a foliation-dip to the south-east. The mica-schist being very fissile, the granite had passed up foliation-planes ; but the hornblende-schist is very tough and comparatively non-fissile, so that the planes of least resistance are probably joints. There was not the slightest indication of a melting-up of the schist, the lines of junction being quite sharp. But if a general fusion had taken place, some of the hornblende-schist must have undergone the process ; for its foliation-planes end abruptly against the granite. We can hardly believe, however, that a rock which is nearly all hornblende could have been melted up into a highly acidic granite. The foliation in the granite I will discuss further on ; and will simply remark here that, on the metamorphic hypothesis, it is singular for granite in mass to be foliated, while the narrow bands between the schist-fragments show no trace of foliation.

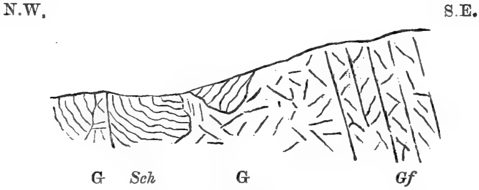
Section on Lough Greenan (fig. 1, south-east end, p. 223).

Leaving the Gap, I now struck to the north-east along the eastern slopes of the granite mass of Crockmore, and in one place collected beautiful hand-specimens showing the contact between granite and schist. I then attacked the scarp which overhangs the pass at the south end of Lough Greenan. The lowest rock seen was hornblende-schist, with a moderate S.S.E. dip, overlain by a lead-coloured, friable mica-schist. We next come, after a short interval, to a band of blue compact limestone, slightly micaceous, dipping E.S.E., passing under hornblende-schist, these strata forming the steep escarpment overlooking the south-eastern side of Lough Greenan, and being surmounted by the quartzites and associated strata which rise into the steep hills overhanging the eastern margin of Lough Salt.

Prof. Hull places an unconformity between the lead-coloured schist and the limestone, assigning the former, with the underlying hornblende-schist, to the Laurentian, and the limestone and associated rocks to the Lower Silurian. There is certainly a discordance, as is indicated by the dips in my section ; but such local variations of strike occur too often in this and other disturbed regions to justify so important an inference. The strike in this district, a little further from the granite, is to the S.W., and therefore not agreeing with either of the strikes in the section, but coinciding

with the trend of the schist within the granite of Barnesbeg Gap. The lithological evidence is decidedly against the creation of two formations. The hornblende-schist of the so-called Laurentian is specifically the same as that above the limestone, and cannot be distinguished in hand-specimens from rocks on the other side of the granite, near Creeslough, which are placed by Prof. Hull in the Lower Silurian. The lead-coloured schist, too, may be matched over and over again in the supposed newer series on both sides of the granite promontory. It should also be observed that these schists, hornblendic and micaceous, are fine-grained and thin-bedded, thus differing widely from the massive gneisses of the Laurentian, whether in Scotland, the Malvern Hills, or the Wrekin. On the whole, I can see no reason of any serious weight for separating the schists in or near the granite from the ordinary schistose rocks of the region.

Fig. 2.—*Section West of Croagh.*



G. Granite. *Gf.* Foliated Granite. *Sch.* Schis

Section west of Croagh (fig. 2).

Coming to the western side of the granite promontory, we find a second junction between the granite and the schists on the main road west of Croagh Hill. The breadth of the granite, where it is crossed by the road through Barnesbeg Gap towards Creeslough, is about three miles. Approaching the western margin of the promontory from the east, we observe that the foliation in the granite becomes very marked. In one spot there is a clear dip to the S.E. at 80°. This rock is mainly composed of felspars, one of which is orthoclase, and black mica. The foliated structure is seen, not only in a linear arrangement of the mica, but also in a distinct striping of light and dark bands, corresponding in direction with the strike of the mica, the dark colouring being due to the abundance of that mineral.

A few yards beyond we come to the junction. The rock next to the granite is a thin-bedded, flaggy, grey schist, containing a whitish mineral, which Prof. Bonney is disposed to think hornblendic. I would suggest that the occurrence of this mineral may be due to the presence of granite in the vicinity of limestone, of which there are signs near at hand. A granitoid material is also seen to penetrate a rock which Prof. Bonney considers pyroxenic. I am inclined to regard this as a case of intrusion of granite in limestone, with subsequent chemical reactions. In Prof. Bonney's opinion, some of the

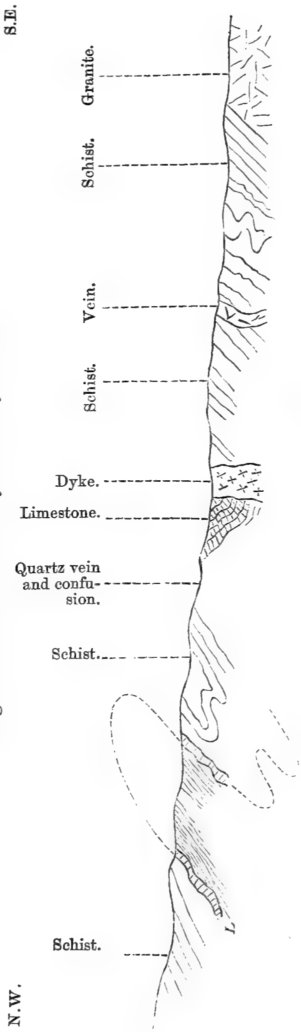


Fig. 3.—*Section North of Dunlewy Church.*

L. Limestone, repeated in folds.

felspar has probably been converted into saussurite, a change which would, of course, support my suggestion; but he does not consider that the slide examined by him displays evidence of a junction. However, I leave my hint to be confirmed or refuted by further observation. Except in the immediate vicinity of the granite, the rocks are ordinary mica-schists, at first dipping away from the granite, and then bending up to the N.N.W., in accordance with the usual dip of the rocks west of the promontory. These schists are also contorted on a smaller scale, and penetrated by veins of quartz and a coarse granite. The section thus appears to furnish another example of the intrusion of the granite.

Section in the road north of Dunlewy (Protestant) Church (fig. 3).

This locality is also at the western margin of the granite, but ten miles further south. Commencing east of the road, where it begins to turn round to the north, we leave the granite, which is coarsely crystalline and unfoliated, and, on the other side of the road, come to mica-schist, containing a mineral which Prof. Bonney thinks may be allied to kyanite, and he agrees with me that this mineral may be the result of contact-alteration. This rock dips north-westerly, and is followed by quartzose schists highly contorted, and penetrated by a vein of fine-grained granitoid rock. Then follow in succession friable schists, a thin band of limestone, and lead-coloured mica-schists, repeated again and again by folding and fracture till

we come to the Errigal quartzite. The secondary contortion is at some points very great, and the numerous disturbances render the reading of the ground somewhat perplexing. The schists and limestones are penetrated by several quartz veins and a dyke of dolerite. Similar schists, especially the quartzose and lead-coloured varieties, occupy much of the ground as far west as the sea, and crystalline limestone also occurs near the coast. In fine, I can see no reason whatever for separating the schists east of Errigal from those to the west, and assigning the former to the Laurentian system. There may be a fault between the Dunlewy schists and the Errigal quartzite; but this does not afford sufficient ground for evolving a second formation out of a section which, from Dunlewy to the Atlantic, displays alternations of similar rocks.

The three sections thus described supply the main evidence which has been relied upon for proving that the granite has resulted from the metamorphism of sediments, that it is associated with certain schists and limestones, supposed to be of the same age, and separated by a fault on the west and an unconformity on the east, from similar schists and limestones which have been called "Silurian." The facts adduced by me appear to favour the hypothesis that the schists on both sides of the granite are of (approximately) the same epoch, and that the granite has been intruded as an igneous mass. Further evidence of the igneous origin of the granite is supplied by the descriptions which follow.

Ground round Bunbeg.

At Dunlewy (fig. 3) the western margin of the granite turns round and strikes to the west for several miles; but towards the coast the granite projects to the north in a second tongue, near the base of which Bunbeg is situated. The rock about this village is coarsely crystalline, and, so far as I could ascertain, destitute of foliation. Several masses of quartz-schist, some of, perhaps, an acre in area, others mere hand-specimens, are immersed in this granite, which also sends veins into the schist, and sometimes overlies it. Limestones also occur, and have undergone great alteration near the igneous rock. A very interesting combination of facts is seen in a low, flat-topped elevation, situated near the "e" of "Bunbeg" on the Ordnance Map. The western escarpment presents a face of bedded limestone, highly crystalline and very full of garnets, some seams being crowded with large, well-formed, brownish-red crystals, while others consist of garnet-rock. The bed at the base of the section, in presumed proximity to the granite, is a *mélange* of minerals, amongst which Prof. Bonney recognizes garnet, more than one member of the hornblende group, and perhaps staurolite. I have little doubt that these minerals are produced by the contact of the granite. Rock is covered between the limestone and the eastern end of the monticule. Here quartz-schist crops out in a low cliff, at the top of which a vein of granite is very clearly seen to penetrate and overlie the schist. As the limestone and schist both dip at a low easterly angle, there is probably a fault between them,

and this weak point may have permitted the intrusion of the granite. The schists of this locality have usually an easterly dip, and are frequently intensely contorted.

That this granite is intrusive is perfectly certain, and there is no doubt that it is continuous with the promontory of gneissic granite.

Granite of Dunaff Head and Malin Head.

South-east of Dunaff Head rock is well exposed on the flat bare shore. For some miles to the S.E. the region is occupied by quartzite; but north of Lenan Head granite comes in, appearing amidst the quartzite in irregular masses and sending out veins. On the same strike, to the N.E., granite is exposed on the south side of Malin Head, and is clearly intrusive in the quartzite of the district.

Prof. Bonney has examined microscopic sections of granite from all the localities described, except the last, and he is of opinion that they "exhibit traces of an original igneous structure, which appears to have been much modified at a later time."

4. The Foliation in the Granite.

It seems to have been generally assumed that the presence of a gneissic structure in a rock is a certain proof of its metamorphic origin; but this opinion has never been justified by facts. There is no *à priori* reason why an intrusive igneous rock should not be foliated. Of late years we have acquired larger views of the effects produced by pressure. A lateral force which could thrust regional masses of Hebridean gneiss over newer rocks to the breadth of a mile, and squeeze a north-western into a north-eastern strike along a line of many miles in length, may well be capable of producing a foliated structure in a band of granite some three or four miles in width. Certain parts of the Donegal granite mass are incontestably intrusive in the schists. Which view, then, must we adopt: that the granite is igneous, with a gneissic structure subsequently superinduced; or that it was originally part of a mass of bedded sediments, some portions of which have been heated to the point of fusion? As the question is one of considerable theoretical interest, a careful review of the evidence is desirable.

Arguments for the Metamorphic Origin of the Granite.*

(1) The Granite is "gneissose in character."

This fact I hold to be consistent with the igneous theory.

(2) It occurs "in thin beds corresponding to the bedding of the stratified rocks of the district."

If this means that the strike of the foliated granite corresponds with the strike of the district, it is sufficient to say that this would also be the case on my hypothesis. But if these words imply that the granite is truly stratified, I reply that, in the typical section at Barnesbeg Gap, the granite lies between the masses of schist, not in beds, but with the irregularity of an intrusive rock.

(3) In the granite oligoclase occurs associated with quartz. This

* R. H. Scott, Journ. Geol. Soc. Dubl. vol. ix.

would be "hardly possible," if the rock had been in a "state of simple fusion." But the granite has been in a state of fusion on either hypothesis, and yet the oligoclase in the presence of quartz has declined to pass into a more acidic felspar. Whether or not the granite was once stratified rock does not matter if fusion has actually been produced.

But the evidence which Mr. Scott most strongly urges is that—

(4) "Far within the limits of the granite" occur "isolated patches of metamorphic rock, not lying *on* the granite, but *in* it."

This fact is in perfect harmony with the igneous theory. Why should not fragments of rock sink down into a molten mass? Or why should not fused matter rise up round masses of schist? If the granite was squeezed up through rocks which were traversed by faults and joints, it would probably carry up some masses before it and become entangled amongst others. The former would be the first to be removed by denudation, so as to expose the subjacent granite, amidst which fragments of the stratified rocks would be preserved.

The Author's Objections to the Metamorphic Hypothesis.

(1) If the granite is simply a metamorphosed portion of a mass originally sedimentary, we should expect to find it graduating into the adjacent schists and limestones. But I have been unable to detect the least evidence of such a passage. The numerous junctions I have seen have been quite distinct, or there has been a slight welding together of the two rocks. Prof. Bonney has microscopically examined sections selected by me as showing the contact of granite with schist—one from Bunbeg, where the granite is unfoliated, and one from Barnesbeg Gap, in the foliated region—and he quite agrees with my interpretation. At Bunbeg pieces of schist no larger than a man's hand are immersed in granite, yet their margins are quite sharp. This surely would be an impossibility if these fragments were merely the unmelted remnants of a series which had undergone partial fusion. On the other hand, these appearances are not uncommon where igneous rocks have been intruded into stratified rocks. For example, on the same coast, near Horn Head, the diorite at one spot is crowded with fragments of contorted schist.

(2) A uniform mass of granite could not have been produced by the fusion of a varied series of strata, including quartzite, quartz-schist, micaceous and hornblendic schists, and limestones. There would surely be bands in the granite corresponding with the materials out of which they were formed. The chemist, too, would be curious to know how granite could be produced by the melting of quartzite, or limestone, or hornblende-schist. I admit variations in the granite, but these give no support to the metamorphic hypothesis. Thus, the granite of Barnesbeg Gap, associated with micaceous and hornblendic schists, is mainly composed of quartz and orthoclase; while in the granite of Dunaff Head, surrrounded by quartzite, plagioclase predominates, and there is a fair amount of mica.

Possible Explanations of the Gneissic Structure.

There appear to be three possible causes of the foliation:—

(1) Flow-structure. The foliated granite may be regarded as a huge dyke. As the molten rock was being slowly forced up the great fissure in which it lies, its motion would be more rapid in the middle than at the sides. This might give rise to a vertical fluxion-structure, on which foliation was subsequently induced.

(2) Pressure during consolidation.

(3) Pressure after consolidation. This hypothesis may take two forms:—

(*a*) Cleavage with superinduced foliation. The gneissic structure is nearly vertical and as regular as cleavage. We know that rocks may be cleaved, and that cleaved rocks may become foliated. In this case there would be two periods of crystallization, the first when the granite consolidated, the second when there was a redeposition of minerals in accordance with cleavage-planes.

(*b*) Pressure-foliation. Prof. Bonney, from microscopical examination, informs me that the granites exhibit signs of great crushing, by which the original structure has been "much modified." I have already (p. 228) suggested that the foliation is probably due to lateral thrust; but I am not prepared, without a more elaborate study of the ground than I was able to give, to pronounce an opinion on the exact mode of operation. The evidence for the existence of the required pressure will be more satisfactorily estimated when the schists have been described.

II. The Schistose Rocks.

These may be separated into two groups:—

(1) *Lough-Foyle Series.*—Semicrystalline: consisting of quartzose grits; quartzite with distinct traces of fragmental structure; fine-grained schists, some of them black; shaly and slaty beds; crystalline limestone and compact dolomite. Usual dip north-westerly. Well exposed in that part of the Inishowen peninsula which lies west of Lough Foyle. The following extracts from Prof. Bonney's notes will be seen to be confirmatory of the above description:—"schistose rock;" "might even be a phyllite;" "fragmental structure still conspicuous;" "schistose slate;" "fragmental structure very marked."

(2) *Kilmacrenan Series.*—Crystalline: consisting of true quartzites, quartz-schists, mica-schists, hornblende-schists, schists with hydro-magnesian silicates, and crystalline limestones. Dip south-easterly. Occupying a large part of the district or barony of Kilmacrenan, lying to the west of the village of that name. Prof. Bonney, in reference to these rocks, writes:—"I should quite agree to the idea of these, or the bulk of these, being old rocks. The majority, however, do not seem of the oldest type." Some of the most typical varieties are described by Prof. Bonney as "mica-schist," "idem, with garnets," "idem, with probably some chlorite or hornblende," "hornblende-schist," of "the Lizard" type, "idem, with garnet and

chlorite," "crystalline limestone, with garnet," "calcareous schist, with some quartz and mica."

Some account of the distribution and relations of the above groups will be given in the following paragraphs.

Section from Londonderry to Dunaff Head (fig. 5, p. 235).

This line passes from S.S.E. to N.N.W. across a band of about 20 miles in breadth, striking to the S.W. The Lough-Foyle series occupies the south-eastern side of the zone, and is 13 miles broad. The remainder of the breadth is covered by the upper part of the crystalline group.

Drumahoe Quarry (two miles E.S.E. of Derry).—The quarry-section is now partly obscured by débris, and rock is better seen in and near the river-bed, where a fine-grained limestone, 3 ft. thick, and some slaty bands, dip E.S.E. at 80°. Near the water-mill, a little lower down the stream, are fine-grained bluish-grey schist and altered quartzose grit, rather contorted, dipping at a low angle to the N.W. The schist is of the peculiar type so characteristic of the hypometamorphic rocks of Anglesey. At first sight it might be taken for shale or slate; but looking more closely we see the surfaces of the laminæ glistening like the folia of a true mineralized schist. This view is confirmed by the microscope. Prof. Bonney considers the rock a schist of a late type, in which the fragmental structure is still conspicuous. I call special attention to this variety, because it predominates throughout the newer Archæan rocks of Ireland, wherever I have seen them.

Londonderry.—Near the east end of the Foyle Bridge there is a large quarry of normal hypometamorphic schist, dipping N.W. at 60°. On the west side of the river, in the Strand, the rock is a quartzose grit, separated into thin seams by folia of mica, and is highly suggestive of the "foliated grit" of Melin pant y Gwyda *, in Anglesey. About two miles north of the city, east of Summer House, there is a good exposure of similar schistose grit in a small quarry. The beds are puckered into gentle undulations, such as might be mistaken for ripple-marks. A mile and a quarter due west of this section, in some large quarries on the Buncrana Road, is an extensive exposure of rock which differs from the preceding only varietally. The gritty materials, consisting of quartz and felspar, are very clearly fragmental. The schist is very fine-grained, often occurring as mere flakes in the grit, sometimes in regular seams. The dip of the rocks hitherto examined west of Londonderry is usually N.N.W.

Cashel Hill.—This elevation, four miles N.W. of the last locality, is the spur which terminates Scalp Mountain on the S.W. The rock is of grit, arranged in thin regular seams, and little of the schistose material is present. The bedding, a little contorted, dips N.N.W. at from 30° to 60°. This grit passes down through gritty beds with schistose interlaminations into intensely contorted satiny schist, in folia so thin that, but for the micaceous lustre, we should

* Quart. Journ. Geol. Soc. (May 1881), vol. xxxvii. pp. 222, 234.

call it shale. Some of it is black. Lower down the slope, in the quarry west of Burnfoot, we have grit and black schist closely interfoliated, the folds being reflexed to the S.E. Some of the grit is massive, and its contortion can sometimes only be determined by observing the behaviour of the associated schists.

Shore north of Fahan Station.—At Fahan we reach Lough Swilly, and our section keeps to the eastern margin of this picturesque arm of the sea up to Dunaff Head. Rock is well exposed on the shore, grits and black schist being still the prevailing types. Some of the latter is still more modern-looking than at Cashel Hill, and Prof. Bonney agrees in thinking it is not far removed from phyllite. The beds stand at very high angles to both N.W. and S.E., and are sometimes vertical. The evidence of lateral thrust is very pronounced. The strata are not only crumpled into numerous folds, but in some places are crushed into masses of angular fragments thrown together with their divisional planes lying at all angles. This pressure is not evenly distributed. For example, the grit in one place is normal, differing only from a Palæozoic grit in the mineralization, entire or partial, of the matrix; but at a little distance, where the crushing and contortion are more intense, the particles of grit are flattened, and strong folia of a silvery mineral (? talc) come in between them, so that the rock approaches a schist in structure. It is not difficult to understand that if the squeezing process were carried still further, the fragmental structure might be entirely obliterated, and a true schist be formed. This suggestive case is not unlike examples I have already described elsewhere*, where the thrust of the Caledonian gneiss in Sutherland has converted quartzite into quartz-schist. The overthrust in this locality is to the N.W., and the same fact is to be observed at Buncrana, about two miles further on.

I did not see any limestone in the section between Derry and Buncrana; but the Culdaff limestone is on the strike of the rocks east of Buncrana, and pieces of it, as well as of a similar variety at Illies, near Buncrana, have been kindly furnished me by Mr. R. J. Cruise, of the Irish Geological Survey. These limestones are dark bluish-grey in colour, and are intermediate in degree of crystallization between the Drumahoe limestone and the limestones of the crystalline schistose series.

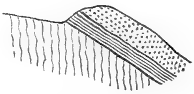
Between Buncrana Bay and Ballynarry Bay.—We commence this part of our section at Ned's Point. Again we come upon the black schist. It is here associated with a hard quartzose grit and a quartzose micaceous schist. The dip for some distance is to the N.W. at 20°–30°. The same beds are repeated again and again in a succession of reversed faults of the structure represented in fig. 4, a bed of grit, underlain by a seam of the black schist or phyllite, resting unconformably upon a coarse schistose rock, dipping at a high angle in the same direction. Sometimes black schist is wanting, and the grit is in contact with the coarse schist. In one place a seam of the last-named rock is bent into a series of V-shaped folds,

* Geol. Mag. Dec. 3, vol. i. p. 221.

while a bed of grit in contact with it remains uncontorted. The grit-bands and coarser schists occupy the shore to Porthaw. Here the dip changes to S.E., with much contortion and frequent intrusion of quartz-veins.

Fig. 4.—*Thrust-plane.*

S.E. N.W.



At Hegarty's Rock the strata are largely of quartzose grit. Quartzite comes in for the first time. It differs from the quartzites of the crystalline series in presenting even to the naked eye evidence of fragmental structure in the occasional occurrence of angular grains of quartz. The strata of grit and quartzite dip at a low angle to the N.W., and each bed is sharply cleaved for a distance of several inches from the surface inwards. North of Hegarty's Rock, the succession is clear, the grit being overlain by the quartzite, and the quartzite by the fine and coarse schists, the whole undulating at a gentle angle to the N.W. The beds then lie in a low broad anticlinal arch; but the oblique foliation of some of the seams of schist points to the continued action of lateral thrust. Towards Ballynarry Bay the strata begin to rise to the N.W., and the outcrops terminate at the sands of the bay in a considerable thickness of quartzose beds and thin schistose bands, the whole dipping to the S.E.

This brings us to the north-western edge of the subcrystalline band. We have seen that at the eastern side fine-grained schists and schistose grits prevail. West of these we have more massive grits and black phyllites or schists; and further west similar types are again seen, associated with quartzites and quartzose schists. The state of alteration is tolerably uniform from east to west, the beds which exhibit the least crystallization being perhaps the black schists, occurring most conspicuously in about the centre of the traverse. The dip being usually to the N.W. and N.N.W., the thickness might seem to be considerable; but there appears to be frequent repetition by both folding and faulting, the folds at first being thrown over to the S.E., then to the N.W., and again to the S.E. This alternation of thrusts would be explained if we supposed each series of folds whose axes dipped in the same direction to occupy one slope of a large monocline. Though the thickness of strata may not be great, there is sufficient variation from east to west to show that the same beds are not repeated throughout the traverse. With my scanty knowledge of these rocks, I cannot say what is the true order of the strata; but I am disposed to think that the succession rises from west to east. The beds at the western margin of the subcrystalline band dip away from the metamorphic series, but I do not ascribe decisive weight to this evidence.

Between Ballynarry Bay and Dunree Head.—The bay is about half a mile wide, its south-eastern boundary being formed of the

rocks just described, while along the north-western side runs a wall of strata of the metamorphic group. The only rock which appears in the interval is a mass of coarse diorite, which projects from the sands about midway between the two schistose series. In this line of section, then, the two groups are separated by igneous rock, apparently an intrusive mass.

Continuing the section, we find the beds for the first half-mile lying anticlinally, and consisting of quartzites of the older type, quartz-schist, mica-schist, and subordinate bands of chloritic or talcose schist. We then come in succession to quartz-schist with garnets, talcose or chloritic schist, and a considerable thickness of quartzose schist. A mass of diorite next appears. Beyond this is a beautiful silvery schist, underlain by a black variety, much more strongly foliated than the black schist of the younger group. Then, for a considerable distance, the prevailing rock is green micaceous and talcose schist*. These rocks I followed to within a mile and a half of Dunree Head. The dip of most of the above schists is to the S.E., and there is frequent contortion. I was prevented from visiting the section beyond; but the rocks on the same strike to the N.E. and S.W. are quartz-schists.

From Dunree Head to Dunaff Head.—Dunree Head terminates the quartzite range over which the pass of Mamore is carried. It is composed of easterly-dipping quartzite, and the same rock forms the precipices which overhang Lough Swilly for nearly three miles to the north, and again appears in Lenan Head, north of which the granite soon comes in, and is continued to Dunaff Head. Mr. Cruise informed me that this fine headland is composed of granite and quartzite.

The superficial appearance presented to us by the traverse N.W. of Ballynarry Bay is that of a considerable thickness of quartzite, overlain by a great succession of quartzose, micaceous, and talcose or chloritic schists. This series is certainly quite distinct from the rocks between Buncrana and Derry. It nowhere presents under the pocket-lens, so far as I have seen, any traces of a clastic structure. The schists are well foliated. They do not, indeed, suggest the highly crystalline rocks of the Hebridean system, but they are on the other hand easily distinguished from the partially mineralized schists of the Lough-Foyle series.

It is also to be noted that, while the older rocks dip almost uniformly to the S.E., the dip of the Lough-Foyle group is north-westerly. That this is not a true synclinal structure is evident from the great dissimilarity between the rocks of the two sides of the apparent basin.

Section from Malin to Malin Head.

This traverse is substantially the same as that part of the last section which passes over the older series. Between the village of Malin and the quartzites of the west coast, a breadth of about three

* I do not commit myself to a definite opinion on the exact mineral nature of some of the schists of this region.

Fig. 5.—*Section from Dunaff Head to Londonderry.* (Length about 20 miles.)

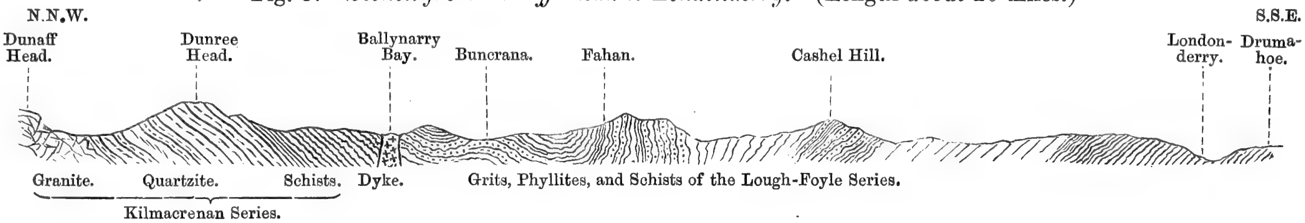
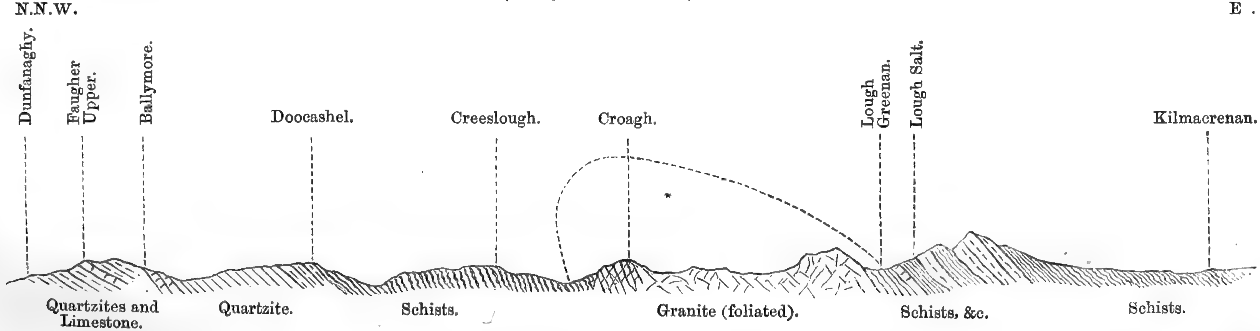


Fig. 6.—*Section from Dunfanaghy to Kilmacrenan.* (The dotted curve is merely a suggestion.) (Length 13 miles.)



miles, we have the micaceous and talcose (or chloritic) schists. They are frequently folded, and in addition are intensely crumpled in numerous small contortions. The dips are alternately N.W. and S.E., but sometimes there is more north or south in them. These schists are frequently penetrated by intrusive diorite. Towards Lag, quartz-schist and quartzite come in, and quartzose rocks are found as far west as Malin Head.

The rocks of Malin Head are on the strike of the quartzites of Dunaff Bay, and are composed of quartzite and quartz-schist. They are bent into an anticline, well seen at Esky Bay. On the south side of the headland, I saw a mass of hornblende-schist, which had apparently been forced up amongst the quartzites by the intrusion of the granite. The extremity of the Head, which is the most northerly point of Ireland, is composed of flaggy quartz-schists, greatly contorted, plunging vertically down to the west.

Comparing the mica-schists of this traverse with the similar rocks in the last section, we find the alternating dips west of Malin represented on Lough Swilly by a tolerably uniform dip to the S.E. The great apparent thickness of strata on Lough Swilly may therefore be explained by repetition.

Section between the Granite of Croagh and the Diorite of Horn Head (Dunfanaghy). (Fig. 6, p. 235.)

The metamorphic rocks of Lough Swilly and Malin are only the upper portion of an extensive succession. If the quartzite of Dunree Head be followed on the strike to the S.W., it is seen to coincide with the quartzite ridge of Lough Salt, where it is underlain (p. 224) by schists and limestone. These are the lowest rocks east of the granite promontory.

West of the granite of Croagh, we pass through a succession of micaceous and hornblendic schists, underlain at Lough Natooey South by bedded crystalline limestone with seams of mica and some quartz, the dips being usually to the S.S.E. at 80°. There is a general resemblance between these rocks and those east of the granite, but the dip is much higher and is occasionally vertical.

At Creeslough there is an apparent thickness of several hundred feet of well-foliated mica-schist, dipping conformably with the preceding rocks. Omitting numerous masses of diorite, we find the following descending succession between Creeslough and the coast.

Stream east of Derryharriff.—Mica-schist of the lustre and colour of black lead.

South of the R. C. Chapel at Doocashel.—Similar schists, dipping S.S.E. at various angles, some low.

East of Chapel.—Quartzite with low S.S.E. dip.

Bridge south of Ballymore Church.—Quarry of coarsely crystalline massive limestone. Colour white; some bands blue; the former sometimes with folia of mica. Dip S.E. at 40°–50°.

Road north-west of Church.—Quartzite with low dip or horizontal; in places greatly contorted.

South of Faugher Upper.—Quartzite.

Faugher Upper.—Crystalline limestone like the beds south of Ballymore. Dip at a low angle to S.S.E., passing below the quartzite. This limestone is continued along the road to Dunfanaghy for about a mile.

Round Dunfanaghy.—Quartz-schist is almost the only bedded rock which appears below the limestone. It is well seen in the shore, west of the town; in quarries one mile to the S.S.W.; in Doorus Point; and in parts of Horn Head. Near Horn Head House, to the N.N.E., the schist in a hillock presents a fan-shaped arrangement. Elsewhere the schist dips at low angles, and is apparently conformable to the limestone.

The apparent descending succession in the metamorphic series is thus summarized:—

1. Micaceous schist of Lough Swilly.
2. Quartzite of Lough Swilly and Lough Salt.
3. Schists (hornblendic and micaceous) and limestones of Lough Greenan.
4. Similar rocks west of Croagh.
5. Mica-schist of Creeslough.
6. Lead-coloured schists south of Doocashel.
7. Quartzite of Doocashel.
8. Crystalline limestone south of Ballymore.
9. Quartzite N.W. of Ballymore.
10. Crystalline limestone of Faugher Upper.
11. Quartz-schists of Dunfanaghy.

We have seen (p. 236) that in Malin Head the granite occupies the core of an anticlinal fold, with vertical strata in the western limb, as if there had been a thrust from the east. In the last section, too, the strata on each side of the granite are similar, and the rocks on the west side are nearly vertical; but I cannot venture with my present information to say that the same structure exists in both cases, though the matter is one which it would not be difficult to determine.

Section between the Granite north of Dunlewy Church and the Granite at Bunbeg.

This section is drawn across the same rocks as in the last traverse, at a distance of about 12 miles to the S.W. We are here near the broadened base of the granite promontory, and the continuation of the beds of schist west of Croagh is apparently cut out by it. The following is the probable succession:—

1. Dunlewy schists; possibly representing the Creeslough series.
2. Quartzite of Errigal; apparently on the strike of the quartzite at Doocashel.
3. Lead-coloured schists at Bunaninver Bridge.
4. Quartz-schist between Gweedore Hotel and the western granite, and crystalline limestone at Bunbeg, probably on the horizon of the rocks round Dunfanaghy.

It is interesting to note that the Dunlewy schists dip to the N.W., that is, in the opposite direction to their presumed equivalents near Creeslough. This fact illustrates the difficulty, in these disturbed regions, of determining the original position of the beds.

III. Proof of Lateral Thrust.

From the preceding descriptions, it will be seen that there are two prevailing strikes in this region, one to the W.S.W., the other to the S.W., and that these strikes are found in both groups.

In fig. 5, the strike of the Lough-Foyle series is W.S.W., between Londonderry and Cashel Hill; but between Fahan and Ballynarry Bay it is S.W., and this is the strike of the older series right up to the granite, and in the granite itself.

West of Malin the older schists strike sometimes W.S.W. and sometimes S.W.; but in the quartzose series further west the strike is S.W.

In the Kilmacrenan section (fig. 6), the trend is almost uniformly to the W.S.W. from the granite to the west coast.

These observations are corroborated by an interesting section in Croaghmore, a mountain W.N.W. of Letterkenny. This elevation trends east and west, in agreement with the strike of the strata, which consist of strong mica-schists dipping steadily to the north, with perhaps a few degrees of west. Near the summit the schists form a low escarpment facing to the south, and these scarp-faces display intense contortions, with small folds reflexed to the east. These two systems of folding must have been produced by earth-thrusts acting in different directions and at different epochs.

The facts indicated do not suffice for a complete induction, but they are enough for my purpose. During one of the periods of contortion, the thrust came from the S.E. or the N.W., probably the former. This pressure was capable of producing the foliation in the granite and the south-west strike in the schists on its eastern side; for, as we have seen, it was violent enough to squeeze hard grits into schist-like rocks, to crush strata into masses of angular fragments with the divisional planes lying in all directions, to produce cleavage in coarse grits, to contort rocks into closely appressed folds, to throw over the folds, and sometimes to give rise to thrust-planes. It was probably during this important corrugation of the crust that the granite was squeezed up from below. At any rate, the lateral thrust easily accounts for the gneissic structure, which may have been in part acquired during the extravasation and completed after consolidation by a continuance of the pressure, or entirely produced after consolidation.

The production of regional foliation by pressure in the case of the Donegal granite may have an important bearing upon the origin of the crystalline schists.

The Rev. E. Hill, F.G.S., has called attention * to a gneissic structure in the granite of Guernsey and made a similar suggestion in reference to some gneisses.

Summary of Results.

1. The granitic rock of northern Donegal, originally supposed to be the result of the metamorphism of sediments, and recently re-

* Quart. Journ. Geol. Soc. vol. xl. p. 419.

ferred to the Laurentian system, is a true igneous granite, as seen in its intrusion into the adjacent schists, in its inclusion of masses and fragments of other rocks, and in its metamorphic action on limestone in contact.

2. This granite is distinctly foliated, the gneissic structure being caused by lateral pressure (probably from the south-east), of which there is evidence in the marked cleavage and intense contortion of strata, in their occasional fractured and crushed condition, and in the frequent overthrow of folds and overthrust of faulted masses.

3. The granite is intrusive in a thick group of quartzites, quartz-schists, hornblendic, micaceous, and talcose (?) schists, and crystalline limestones, called the *Kilmacrenan Series*. These rocks are truly crystalline, but usually thin-bedded and fine-grained.

4. The crystalline schists are bounded on the east by a semi-crystalline series, consisting of quartzose grits and itacolumites, quartzites, crystalline limestones, compact dolomites, phyllites, interlaminations of grit and schistose matter, and finely foliated micaceous schists. These may be designated the *Lough-Foyle Series*.

Discussion *.

Mr. Rutley remarked that there seemed to be no greater reason for surprise at the inclusion of large masses of schists &c. in intrusive granite than at the occurrence of small fragments, or "horses," in dykes. In connexion with the change of limestone into garnets, he inquired whether the limestone was siliceous or aluminous. He also objected to the use of the term "mineralized grit," and inquired what was to be understood by it. He doubted whether Dr. Sterry Hunt's correlations ought to be accepted in the present instance.

Mr. R. H. Scott had hardly expected his paper to be exhumed after the lapse of twenty-two years. He objected to the title of Dr. Callaway's paper; it should have been on part of the north-west of Donegal instead of on the whole county. The granite of Barnesmore was of a different type from that of the district described in this paper, which is similar to that of Argyllshire. When he had worked upon these granites microscopic examination of rocks was not so well understood as it now is; and he could not investigate the rock thoroughly. He had not assigned any particular age to the granite, and he had expressly alluded to intrusive veins, though he considered the rock to be metamorphic. There were similar beds north-west and south-east of the granite in the north, showing a possible anticlinal. He remarked that Dr. Callaway would find work to do in the south of the county and eastward in Tyrone. There are similar altered rocks throughout this region, passing on to fossiliferous beds. There are two

* Portions of this discussion relate to certain views, as to the correlation of the rocks described, which were put forward at the conclusion of the paper, but which were subsequently withdrawn by the author.

types of granite in the main granite district, one with two felspars, the other white like an elvan, and containing sphene. This latter appears in the island of Arranmore. There is a totally different granite further south, near Barnesmore, and that does not exercise metamorphic action on the neighbouring rocks. In conclusion, he inquired, What relation did the beds in Wexford bear to the Silurian near Enniscorthy?

Mr. Teall said that the two portions of the paper struck him very differently. The first portion evidently contained a very interesting record of carefully observed facts, the second portion dealt with the correlation of the schists of the district with those of other localities,—the only evidence for such correlation being a certain lithological resemblance. He was extremely sceptical about the possibility of determining the chronological relations of such rocks in this way, and believed that some of the characters relied upon were merely structural and mineralogical peculiarities, dependent upon the mechanical actions which determine regional metamorphism. The eruptive origin of certain foliated rocks had been clearly established by Darwin, Forbes, Kjerulf, Lehmann, and many other observers. The development of micaceous minerals in connexion with regional metamorphism was a common feature; and he especially referred to the gneissose flagstones and associated schists of the north-west of Scotland. The mica in these schists appeared to be developed at the expense of felspar. In some cases "eyes" of felspar remained, while in the more perfect schists these were almost if not entirely absent. A quartz-felspar grit, such as the Torridon Sandstone, if subjected to regional metamorphism, might thus be readily converted into a mica-schist, and he was strongly inclined to think that some of the eastern schists had been made in this way. The Lough-Foyle and Kilmacrenan series of the author were evidently the result of regional metamorphism, and possibly many original groups had been involved in the action.

Mr. Blanford mentioned that some interesting evidence had recently been brought forward by Colonel McMahon, showing that certain Himalayan gneisses were intrusive. If the differences between the Lough-Foyle rocks and the Pebidian of St. David's were such that these two could not have been identified by mineral characters unless connecting links had occurred in Wicklow and Anglesey, was it not absurd to endeavour to identify either of them with beds in North America? The determination of the age of rocks in distant countries by mineral characters had formerly been applied to sedimentary beds, then to igneous; it had long been abandoned in the former, and was gradually being given up in the latter, and there was much reason for caution in applying the same key to ancient altered formations, the succession in which was often very obscure.

Mr. Marr considered that, in order for the correlation to be safe, the Pebidian must be traced across; but vulcanicity continued up to and throughout Cambrian times, so that Cambrian rocks, if altered, would be undistinguishable from the Pebidian.

The President said that he had been unable to examine the specimens in minute detail, but had carefully looked through them. Of the so-called granites, seven out of eight were certainly, and the remaining one probably, granites. They gave indication of considerable crushing since their first crystallization. Of other rocks there was good evidence of two series, one agreeing in general characters with Scotch schists, the other with the Pebidian of Wales. He doubted Mr. Teall's evidence of the production of all schists by crushing. As regards mineral character, he thought that the general condition and amount of alteration of rocks, rather than their actual mineral composition, should be employed for correlation.

The Author, in reply, suggested that the production of the garnets in the limestone might be due to a chemical action of water from the granite in contact. He regarded a grit as "mineralized" when distinct mineral folia had been produced between the grains. The omission of the word "Northern" before "Donegal" in the title of his paper was an oversight, which he would correct. He had not attempted to definitely correlate the Donegal rocks with any American system, but had merely pointed out certain lithological analogies. His identification of Pebidian rocks in Ireland had not been based only on lithological affinities, but he had specially insisted on their state of crystallization and upon the fact that in Wexford they occurred side by side with unaltered Cambrian and Ordovician sediments, separated from them by sharp lines. The difficulties suggested by some of his critics would, he thought, be removed if it were remembered that in some of the British localities the Pebidian rocks were mainly of volcanic origin. He had compared the Lough-Foyle series with the British Pebidian in the non-volcanic districts.

25. *On a* Skull *of* Ovibos moschatus *from the* Sea-bottom. By W. Boyd Dawkins, Esq., M.A., F.R.S., F.G.S., Professor of Geology and Palæontology in the Victoria University. (Read February 25, 1885.)

In a discussion on my essay "On the alleged Existence of *Ovibos moschatus* in the Forest-bed, and its Range in Space and Time" *, doubts were thrown on the specimen on which the paper was founded as having really been derived from the Forest-bed. On the one hand it was argued by Prof. Prestwich that it was possibly derived from some newer deposit, and on the other by Mr. Evans that it was a dredged specimen. Since the publication of the paper Mr. Clement Reid has carefully re-examined the specimen, and agrees with me in concluding from the matrix that it is "a genuine Forest-bed specimen," and that it has not been dredged †. The interest attaching to the discovery of so arctic a species in the Forest-bed has led me to search for further evidence, and the search has resulted in the discovery of another skull, which is the proximate cause of this communication.

Shortly after the publication of my essay on *Ovibos moschatus* in the Journal of the Society, Professor Newton told me of the existence of an undescribed specimen of *Ovibos* in the University Museum of Zoology and Comparative Anatomy at Cambridge. Mr. J. W. Clarke has been kind enough to send it to me with the accompanying note. "My assistant saw it hanging up outside a general store and curiosity shop in Barnwell, and gave 2*s.* 6*d.* for it. The proprietor of the establishment could give no account of it." An examination of it, however, leaves no doubt on my mind as to its derivation. It is highly impregnated with peroxide of iron, and in one spot between the horn-cores showed traces of the red sand matrix of the Forest-bed. It is stained deep red, as is generally the case with specimens which have been washed out of the Forest-bed and exposed for some time to the sea-water, and it had evidently been at the bottom of the sea for some time, since it is incrusted in places with Polyzoa. The fact, moreover, that these occur on the fractured surfaces proves that the specimen was lying at the bottom of the sea as a fragment. Its sharp angles forbid the supposition that it has been exposed to the dash of the sea on the shingle. In a word, it possesses all the characters of specimens obtained by the fishermen from the North Sea off the coast of Norfolk and Suffolk, and which have been washed out of the Forest-bed at a time when the cliffs now so rapidly retreating were not far from the line of the Dogger Bank.

Between the Dogger Bank and the present cliffs of East Anglia

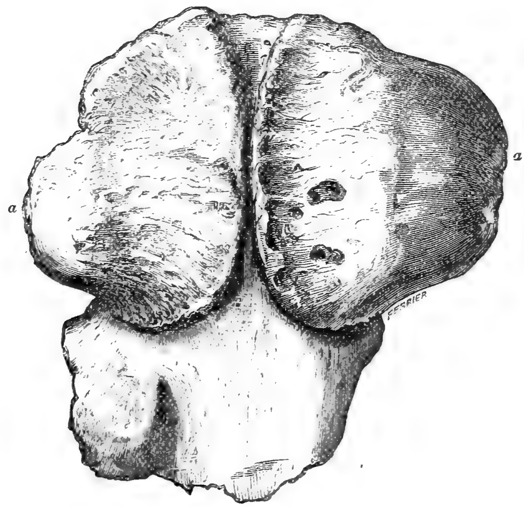
* Quart. Journ. Geol. Soc. Nov. 1883, vol. xxxix. p. 581.

† "Through the kindness of Mr. Buxton, I have had an opportunity of examining the skull, and feel no doubt that it is a genuine Forest-bed specimen. It is certainly not dredged; for the angles are unworn, there are no marine organisms on it, and the loose sand inside is not sea-sand. Under the microscope the sandy matrix is exactly like the coarse quartz-sand of the Forest-bed, and not like the sand of the glacial deposits or shore. A quartzite pebble impacted in a cavity also agrees with the peculiar pebbles found in the Forest-bed." Trans. of the Norfolk and Suffolk Naturalists' Society, iii. p. 632.

the sea-bottom is strewn with similar waifs and strays from the Forest-bed, as may be seen by comparing it with a specimen on the table from Mr. Coleman's collection at Corton. When it is further added that there is no other locality than that of the Forest-bed series on record which has furnished specimens possessed of the above characters, there is, in my opinion, little room for doubt that this specimen was derived from the Forest-bed, and dredged from the bottom of the North Sea, somewhere off the coast of East Anglia.

The specimen in question consists of the coronal and frontal portions of the skull with the horn-cores and the right orbit of an old male Musk-sheep. It has been fractured at the parieto-occipital suture; and the whole of the occiput and the greater part of the basal region has been broken away so as to expose the upper part of the brain-cavity, and to reveal the enormous thickness of the frontals and parietals supporting the horn-cores, the parietal thickness being 2·4 and the frontal 2·1 inches.

Skull of Ovibos moschatus, *Forest-bed.*
(One fourth natural size.)



The horn-cores (*a*, *a*, in figure) occupy nearly all the parietal surface, nearly meeting in the median line of the frontals (*b*), and sweep sharply downwards at right angles to their coronal surface, as is usually the case with old males of *Ovibos moschatus*. They are deeply excavated on the upper surfaces for the insertion of the base of the horns, far more deeply than in any skull of Musk-sheep which I have examined, excepting the skull found in Eschscholtz Bay.

It is comparable to that of the fossil *Ovibos cavifrons* of North America described by Prof. Leidy *. The horn-cores, however, differ

* 'Smithsonian Contributions to Knowledge,' v. Article 3. Journ. Acad. Nat. Sci. Philad. 2nd series, vii. p. 374. See also my British Pleistocene Mammalia, Palæont. Soc. part v. chapter 5.

from those of that species in the fact that they are not confluent in the median line of the frontals, and do not extend in front as far as the plane of the orbits in the median line, as well as in the abrupt downward sweep of their extremities.

The principal measurements, as compared with other specimens, are given in the following Table:—

Measurements of Horn-cores of Ovibos moschatus.

	Specimen figured.	Pleistocene, Crayford.	Recent, Brit. Mus.
Horn-cores, antero-posterior extent ...	6·5 in.	9·0 in.	8·8 in.
" length	6·8	14·5	
" basal circumference	12·1	17·6	14·5
" interspace, behind	1·0		
" " in front	1·5		
" " minimum	0·41	0·65	

The frontals in front of the horn-cores are smooth, and the ridge extending across the forehead in some old males from one supra-orbital *foramen* to another is merely indicated by a gentle rise. In concluding this notice, it only remains for me to add that the skull is the ninth specimen of this rare fossil from British Pleistocene deposits, and the second referable with high probability to the horizon of the pre-glacial Forest-bed.

Discussion.

Mr. Clement Reid doubted whether the specimen described really came from the Forest-bed. It looked more recent and was lighter-coloured. He also called attention to the fact that the specimen brought for comparison, and stated to be from the Forest-bed at Pakefield, had on it traces of marine organisms, and a label stating that it was dredged at a distance of 30 or 40 miles off Southwold.

Dr. Woodward remarked that both the specimens exhibited appeared to be from the Dogger Bank. More information was required to determine whether these specimens were pre- or post-glacial. At the same time the evidence collected by the Author was of great importance.

Mr. E. T. Newton also doubted whether the age of these fossils was satisfactorily established. Their appearance was insufficient to determine that they came from the Forest-bed, because many fossils have been referred in collections to this bed, which were really of unknown derivation, especially certain specimens which were of a dark colour outside and paler within. Specimens from the Dogger Bank were generally heavier than those from the Forest-bed.

The Author in reply said that the only point agreed upon seemed to be that the specimen was dredged in the North Sea. During the last twenty-five years he had studied the Mammalia of the Eastern Counties, and was acquainted with the collections from the Dogger Bank. These were less mineralized and lighter than those of the Forest-bed. The skull, in his belief, was identical in mineral condition with undoubted Forest-bed specimens.

Geol. Soc. Vol. XLI. Pl. VI.

MINING DI... RICT IN THE

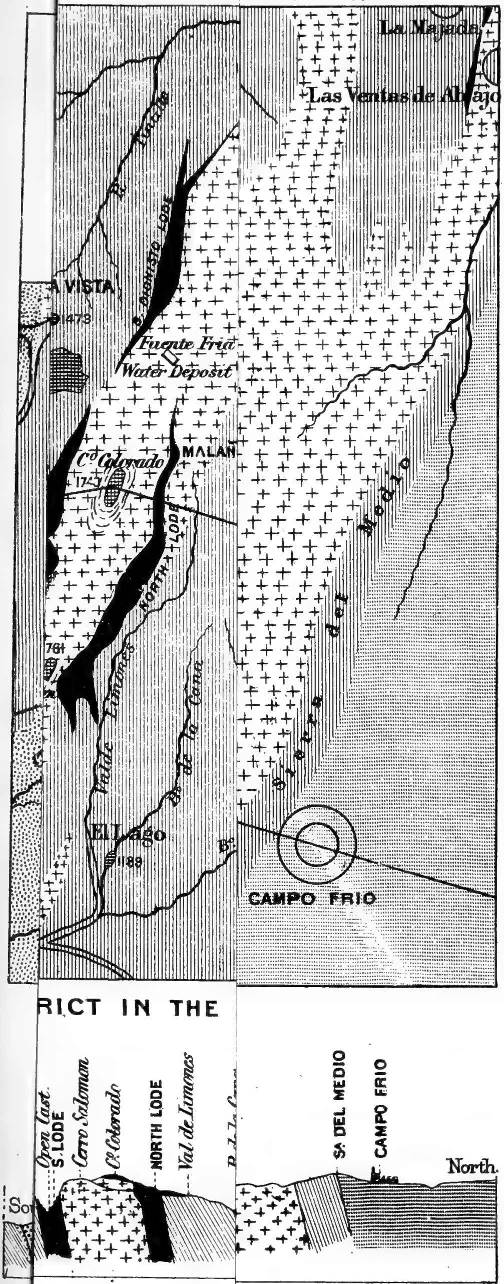


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FIG. I. MAP OF THE RIO TINTO MINING DISTRICT. SCALE $\frac{1}{40.000}$.

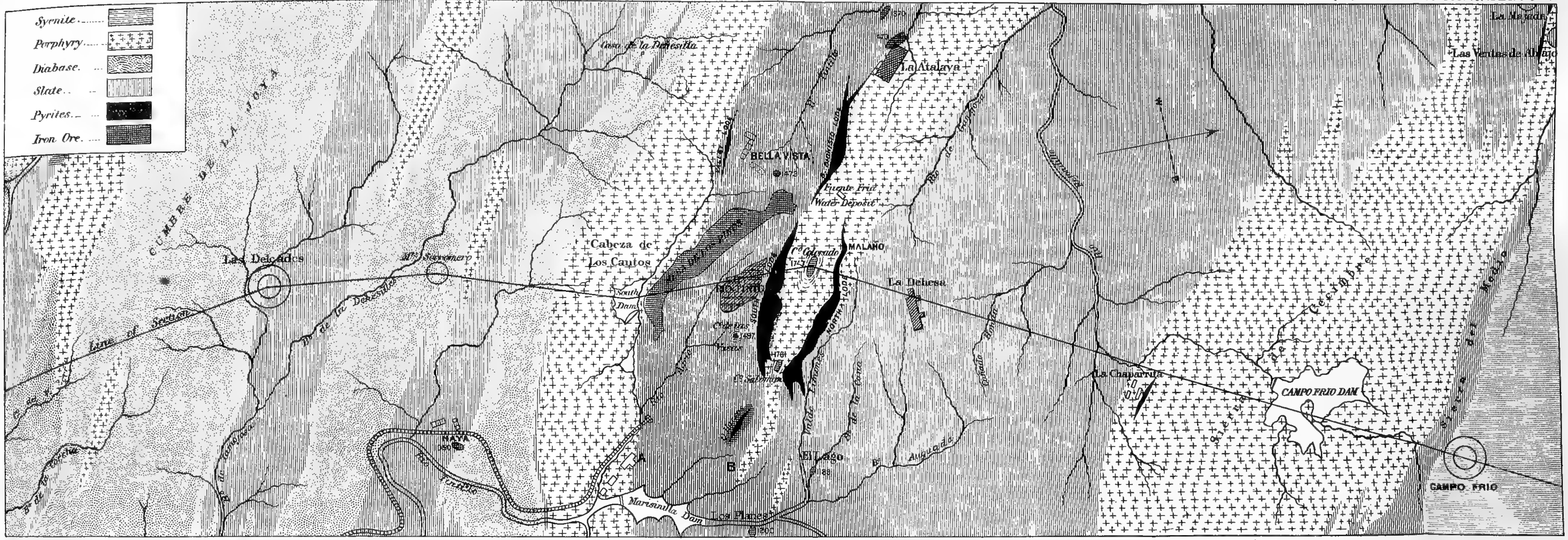
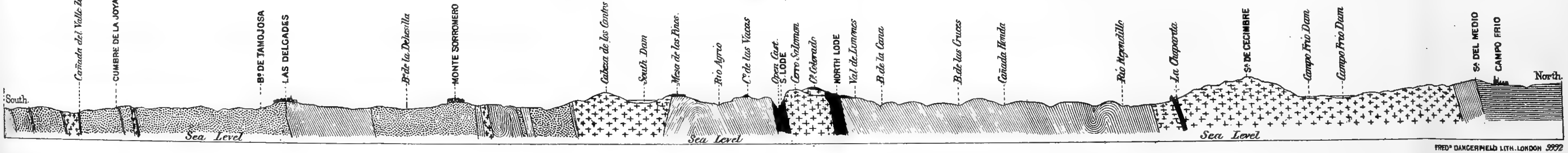


FIG. 2. SECTION ACROSS THE RIO TINTO MINING DISTRICT IN THE LINE SHOWN ON THE MAP. SCALE $\frac{1}{40.000}$.



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26. *On the* Geology *of the* Rio-Tinto Mines, *with some* General Remarks *on the* Pyritic Region *of the* Sierra Morena. By J. H. Collins, Esq., F.G.S. (Read January 28, 1885.)

[Plate VI.]

1. *Introduction.*

The pyrites deposits of the Andevallo, as the mineral zone of the south-western branch of the Sierra Morena is called, are certainly the most extensive ever yet discovered. In addition to the world-famous mines of Rio Tinto and Tharsis in Spain, and of San Domingos in Portugal, they include many others of very considerable extent and importance, yielding in the aggregate, at the present time, upwards of two and a half millions of tons of ore per annum*.

The deposits in question are included within a band of country about 140 miles long and 30 miles wide, consisting for the most part of Palæozoic schists, now known to be principally, if not entirely, of Upper Devonian age, but which are often very highly metamorphosed locally into jasper, talc-schists, chiastolite-schists, &c., and are associated with quartz- and felspar-porphyries, diabase, quartz-syenite, and granite. The mineral strata to the northward abut against or rest upon the highly crystalline schists and gneissose rocks of the Sierra Alta, which have been assigned to the Huronian and even to the Laurentian period, while to the southward they are overlain by Tertiary limestones and sandstones.

The chief mineral riches of this region consist of masses of cupriferous pyrites, such as those so largely worked at the above-mentioned mines; but there are, in addition, numerous veins of manganese ore, as well as of lead, copper, and zinc ores, some of which have been worked occasionally to considerable advantage, while a very large number of them could be so worked were the country more opened up by railways and roads.

2. *General Character and Associations of the Pyrites Deposits.*

Commencing near Aznalcollar and Castillo de las Guardas, in the province of Seville, the masses of pyrites succeed each other at short intervals, proceeding westward through the middle of the province of Huelva to San Domingos in Portugal†. The more important masses are, however, contained within a much more circumscribed zone, which is not more than three or four miles wide at the eastern

* The official statement in the 'Revista Minera' gives 1,720,853 tons as the total production of the Spanish deposits in 1882, since which there has been a very considerable increase. In 1884 the mines of Rio Tinto alone produced 1,369,918 tons of ore, containing on an average 3·234 per cent. of copper.

† This region, besides supplying numerous tributaries to the rivers Guadalquivir and Guadiana, is the source of the considerable river Odiel, which, with its chief tributary the Tinto, enters the sea at Huelva.

extremity, but which divides into two branches in going westward, the smaller and less important trending a little to the north of west towards Aroche, while the greater passes to the south of west into Portugal at San Domingos.

I do not propose to describe this extensive region here *, but the description which follows of the Rio-Tinto district, and of the relations of its mineral deposits to the country rocks, will apply with very considerable accuracy to the whole region, allowance being made for the greatly different extent of the various deposits. The more important mineral masses throughout the region are very frequently true "contact-deposits," and I believe the more closely they are examined the more generally this will be found the case.

3. *General Description of the Rio-Tinto district.*

Briefly the structure of this district may be described as under:—

The greater portion of the country represented on the accompanying map (Plate VI.) consists of Palæozoic slates and schists, striking some few degrees to the north of west, and dipping, for the most part, steeply to the northward. These slates have been pierced by intrusions of syenite, of diabase or dolerite, and of quartz-porphyry and felspar-porphyry. Fissures have then been opened in these rocks along lines of weakness, mostly determined by the junctions of the porphyries with the slates, and these fissures have become filled in their wider portions with rock débris or with pyrites. The section fig. 2, Plate VI., shows the manner in which the various rocks are convoluted and interstratified.

The Slates.—At and around the mines of Rio Tinto these are certainly of Palæozoic age, but their exact geological horizon has only lately been determined. At one time they were stated to be entirely unfossiliferous; then they were said to be Silurian †. Messrs. Römer and Wimmer consider them to be the equivalents of the culm-measures ‡; while Dr. Fraas, of Stuttgart, on the occasion of his visit to the mines in 1883, came to the conclusion that they were of Upper Devonian age, and this conclusion is fully borne out by the examination which Dr. Etheridge has been kind enough to make of the fossils which I obtained and submitted to him. Fossils are tolerably abundant in several places in close proximity to the mineral deposits. As might have been expected, they are usually much crushed and distorted, yet it has been possible to determine several species, the most common being *Posidonomya Becheri*, *P. acuticosta*, *P. lateralis* (?), a *Goniatite* allied to *G. subsulcatus*, and a plant which may be a *Sagenaria*. Don Joaquin Tarin, in his memoir published in 1878, states that he has also met with a little *Goniatite*

* The main portion of this region, that comprised within the province of Huelva, has been very fully and faithfully described by Sr. Dn. Joaquin Gonzalo y Tarin in the 'Boletino de la Comision del Mapa Geológica de España,' vol. v. 1878. This author gives also a very good geological map of the Andevallo on a scale of $\frac{1}{200000}$.

† Quart. Journ. Geol. Soc. vol. xxxvii. p. 2.

‡ Berg. u. Hutt. Zeit. Nos. 28–30, 1883.

resembling the *G. crenistria* of Phillips, an *Avicula*, an *Orthoceras*, and two specimens of *Crossopodia*; but these were not found within the area included in my map, although they are stated to have all occurred associated with *Posidonomya Becheri* *. Many of these fossils were found enclosed in concretionary nodules.

Up to the present time fossils have been discovered in eight different localities, all situated within half a league of the village of Rio Tinto, and all within a furlong of the mineral deposits †.

For the most part the slates are either vertical or very highly inclined (see Plate VI. fig. 2); and with a few local exceptions the dip for miles together is northward, while the strike is from 15° to 25° north of west. At the surface the slates are mostly weathered to a yellowish or brownish tint, with occasional bands nearly black; but in almost all the excavations a dark-blue tinted rock is soon reached, more or less approximating in character and appearance to roofing-slate. Up to the present time, however, no slate has been met with of marketable value.

The following are analyses made in illustration of this paper:—

(A) is of a specimen taken from an adit-level driven recently by the Ayuntamiento of Rio Tinto into the hill known as the Mesa de los Pinos for the sake of obtaining a supply of drinking water, the place selected being, therefore, situated at a considerable distance from the pyrites deposit. The specimen selected was very dark blue and exceedingly close and compact in texture.

(B) is a sample of weathered rock, originally of very similar character.

		A.		B.
Water by desiccation....	0·26	4·72	0·20	2·70
,, by ignition	4·46		2·50	
Silica		61·12		64·47
Alumina..............		18·95		19·22
Protoxide of iron		9·65		trace.
Peroxide of iron		trace.		9·20
Lime		0·49		trace.
Magnesia		0·72		trace.
Pyrites		0·30		0·10
Alkalies, calc. as potash..		2·19		3·21
Copper		trace.		trace.
Phosphoric acid		0·12		trace.
Loss		1·74		1·10
		100·00		100·00
		Sp. gr. 2·73		Sp. gr. 2·71

* As illustrating the amount of extension which a shell may undergo from lateral pressure, I may here call attention to a statement of the author above quoted that he has in his possession specimens of *P. Becheri*, 160 millimetres (say 6 inches) long.

† The first fossils in the slates were, I believe, found by Mr. Osborne, now the deputy-manager of the Rio-Tinto mines, at the point marked A on the map, while making the railway leading to the Cerro pump. I have found many others at B which seem to be from the same beds, arched over as shown in the section.

It will be seen from these analyses that the result of weathering is to reduce the amount of combined moisture, to dissolve out the lime and magnesia, and to peroxidize the iron. The alkalies do not appear to have been removed in the process of weathering; in fact the second shows somewhat more than the first. All this is exactly what might have been expected of such a rock, in such a climate, where considerable alternations of temperature are continually occurring, while there is ordinarily but little change in the hygrometric condition of the atmosphere.

Reference has been made above to the prevalence of a northern dip at a high angle. In a distance of six miles from N. to S. I have only discovered as yet three anticlinal curves, and this notwithstanding the fact that the bare rocks are everywhere visible. These are shown on the accompanying enlarged cross-section of part of the region shown on the map (Plate VI. fig. 2). It would appear, therefore, that these ancient slates have a very great thickness here as in many other places. The three anticlines referred to may be seen at the Rejondillo near the new bridge, in the valley of the Rio Agrio, and on the Rio-Tinto railway between Naya and Jaramar. In many places the slates are more or less sandy in appearance; they pass, indeed, into a grey fissile sandstone. The development in coarse-grained varieties of these rocks of crystalline particles of quartz and felspar, the latter now for the most part somewhat kaolinized, results in the formation of a rock scarcely distinguishable, except by the use of a lens, from the more schistose varieties of the porphyries hereafter to be described.

In some places the slates enclose fragments of preexisting rocks, rounded or angular. In others small lumps, bands, or lenticular masses of quartzite occur imbedded in the slates, having all the appearance of foreign enclosures, but which I have reason to believe, in some instances, are merely portions of the original rock of more sandy texture than usual, which have become silicified by aqueous agency, the siliceous waters having found in them fit situations in which to deposit their silica. Subsequently the contemporary quartzites have become traversed by joints which do not enter the main mass of the slate, so that the silicified portions completely simulate foreign enclosures. These phenomena may be well seen at several points on the road from Zalamea to Valverde; and they are particularly well marked on the hill between Zalamea and the halfway house on the road to Rio Tinto. Here great masses of this quartzite, some of them several yards in extent and many tons in weight, occur in slate, having all the appearance of included fragments, but which, I believe, have been formed as stated above.

In the neighbourhood of the pyrites deposits the schists are often highly charged with pyrites, as might be expected. I believe, indeed, that they have supplied the material for those deposits, but this part of the subject will be reverted to hereafter.

The pyritous schists near the surface are sometimes changed into ferruginous schists by the oxidation of the pyrites. More often, however, the silicified ferruginous bands which indicate the presence

of pyritous deposits, appear to have been produced by infiltration of mineral solutions from lakes of ferruginous water which formerly existed. The effect of this infiltration has been to indurate the nearly vertical schists in such a manner that masses of them have resisted denudation, and now form ridges higher than the surrounding country. In the neighbourhood of the fissures here, as elsewhere (Agordo, &c.), both schists and porphyries are often bleached and kaolinized.

Jasper.—In a great many places fine-grained bands of the slates following the strike are found to be silicified, and converted more or less completely into excellent jasper, mostly red, but sometimes of a deep green tint. The transition from the unaltered slate to the jasper is often abrupt, but occasionally very gradual, and specimens may easily be obtained in all stages of alteration. The production of this jasper does not appear to be necessarily connected with the presence of intrusive rocks at the surface, since some well-marked bands are situated at a considerable distance from such rocks. At the same time it must be admitted that the finest and most extensive bands are situated very near the porphyries. In many cases these jasper bands accompany bands, nodules, or "eyes" of very pure peroxide of manganese, to which further reference will be made hereafter.

The following (C) is an analysis of one of these red jasper bands from near Bella Vista :—

	C.
Silica	90·30
Peroxide of iron	6·00
Alumina	1·30
Lime	·30
Magnesia	·10
Manganese	trace.
Alkalies	·30
Water	·40
Loss	1·30
	100·00

Assuming that the original slate had pretty much the composition of analysis A, a comparison of this analysis with C will show how great the change has been. It is not merely that there is a great addition of silica, but almost the whole of the other constituents have been carried off except the oxide of iron, and the ratio of that to the silica has been reduced from $\frac{1}{7}$ to $\frac{1}{15}$.

Syenite.—A few miles to the north of the mines is a broad band of syenite running nearly in the same direction as the slates, which I believe to be more ancient than any other of the eruptive rocks of the district. In the neighbourhood of Campo Frio it has a breadth of nearly four miles. It is a perfectly typical quartz syenite, and is itself penetrated by veins and masses of diabase, often much decomposed, and by dykes of quartz-porphyry and of felsite, much resembling the more compact of the elvans of Cornwall. It is also

traversed by mineral veins yielding ores of lead and copper, but of quite a different character from those which yield the pyrites. The soil in the syenite regions is richer than in those composed of porphyry or slate. Further to the north the syenite is succeeded by hornblende-schists, and then again by limestones. I reserve a fuller description of these rocks, which nowhere approach within a league of the mines, for a future paper.

Diabase.—The chief development of diabase is to the south of the mines, where it occurs in extensive masses, in part intercalated with, and in part traversing, the slates. The general strike of these basic rocks is a little to the south of west, and associated with them are others of a fragmentary nature which have much the appearance of altered ash-beds.

The diabase beds are readily discoverable wherever they occur by their brown colour where decomposed, and by their almost universal tendency to spheroidal decomposition. This, in some parts, is so marked that the mule-tracks which serve as roads are strewn with rounded masses of rock varying from a few inches to a foot in diameter. These compel the attention of the traveller, even when not a geologist, owing to the extreme inconvenience which they occasion, especially if he should happen to be a pedestrian. As stated above, rocks of a very similar character are associated with the quartz-syenites which lie more to the north.

The decomposition of this rock produces a very rich soil, which may be distinguished at once by its vegetation from that of the slates and the porphyries, the latter being extremely barren.

The following analysis (D) will fully account for this richness of the soil. The large proportion of "soluble silica" is noteworthy in this analysis:—

D.

Water by desiccation ..	0·50	4·66
„ by ignition	4·16	
Silica insol. in HCl. ..	47·70	49·20
Silica sol. in HCl.	1·50	
Alumina		17·26
Protoxide of iron (with a little peroxide)		12·24
Lime		6·94
Magnesia		4·74
Soda (with a little potash) ..		3·41
Loss		1·55
		100·00
Specific gravity		2·931

The Porphyries.—These are for the most part quartz-porphyries, which have nothing particularly remarkable in their appearance when compared with similar rocks from other districts. Some are more highly quartzose than others, but in all porphyritically developed crystals of felspar of more than microscopic size are extremely rare except in a few localities. Lithologically two varieties are di-

stinguishable, compact and schistose, but passing into each other. In general the interior of a mass is compact, while a schistose structure becomes more and more evident as the outer portions are reached, *i. e.* those near the junctions with the slate. The difference in chemical composition between the two varieties of the porphyry is by no means great; and I am disposed to believe that the schistose structure has been developed by a continuance of the same pressures which have converted the Palæozoic mudstones into slates. Reference has already been made to the existence of bands of porphyritic schists (altered shaly sandstone) in the slates. These so closely resemble the bands of schistose porphyries, that it is not in all cases possible to distinguish between them in hand specimens; indeed, the more one examines these rocks in the field, the more one is disposed to regard them merely as varieties of one and the same rock, serving as intermediaries in bridging over the passage from undoubted slates on the one hand to undoubted felspar-porphyries on the other.

The following analyses of various specimens of the porphyries will show how closely they resemble each other. I add an analysis of the porphyritic schist for comparison:—

		E. Porphyritic schist.		F. Schistose porphyry.		G. Very solid porphyry.
Water over H_2SO_4 by	0·10	0·40	0·25	0·70	0·12	0·40
,, ignition	0·30		0·45		0·28	
Silica		64·50		67·00		76·34
Alumina		23·60		20·30		14·85
Oxide of iron		2·16		2·88		1·89
Lime		1·40		2·80		0·10
Magnesia............		0·40		trace		0·50
Pyrites		trace		trace		trace
Phosphoric acid		0·30		trace		0·05
Alkali as potash		3·20		2·10		5·11
Carbonic acid, fluorine, and loss		4·04		4·22		0·76
		100·00		100·00		100·00
Specific Gravity ..		2·62		2·60		2·65

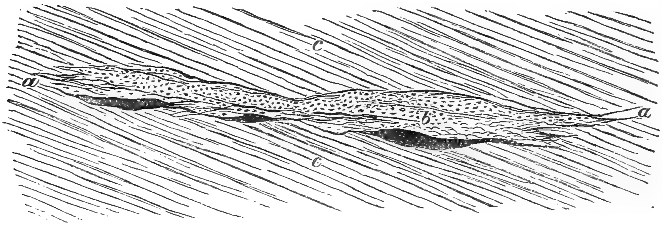
Occasionally, as at the old-station quarry at Rio Tinto, the porphyritic schist may be traced right up to its contact with the compact porphyry, becoming more distinctly crystalline as it approaches the junction, and leaving no doubt in the mind of the observer that the intrusive porphyry has been an active agent in producing the metamorphosis.

It is remarkable how uniform in appearance the porphyries are, even when taken from localities widely separated from each other. Thus I have specimens from Valverde on the south, which cannot be distinguished from others broken near Madroño on the east, and Poderosa in the north.

The porphyritic masses are usually lenticular in form, but they

often have fimbriated extremities as shown in fig. 1, where *a* is the lode-fissure, *b* the porphyry, and *c* the slate.

Fig. 1.—*Section showing Porphyritic Masses.*

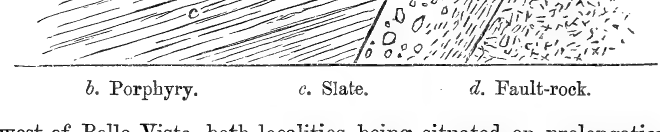


a. Lode-fissure. *b.* Porphyry. *c.* Slate.

Their general direction is so similar to the strike of the slates, and their length is so much greater than their breadth, that they appear to be interstratified, unless the junctions are very closely examined. When, however, such examinations are made, the true nature of the association of the rocks is obvious enough, for the slates abut against the porphyries without in any way bending round them, or else the porphyry breaks up into branches and fingers, which are thrust between the laminæ of the slates as in fig 1. This latter mode of occurrence may be well seen on the hill above Puerto Rubio. A bending of the laminæ of slate around the porphyry is almost if not quite unknown.

In a few places the porphyry appears to be much like granulite. This is particularly observable between the Fuente Fria water-deposit and the first Malaño. Where the porphyries meet the slates by a faulted junction, as is frequently the case, a thick mass of "fault rock" is often observable at these junctions. This may be very well seen in the railway-cutting on the west side of the Mesa de los Pinos (see fig. 2) and on the Zalamea road about half a mile

Fig. 2.—*Section in Railway-cutting on the west side of the Mesa de los Pinos.*



b. Porphyry. *c.* Slate. *d.* Fault-rock.

west of Bella Vista, both localities being situated on prolongations of the "Valley lode"*. It is also well seen at the foot of the hill

* In this railway-fault the slates (*c*) are inclined at a very high angle to the north. They only appear to have a low angle because of the direction of the line of section, which forms but a very small angle with the line of strike.

below Gangosa, on the western prolongation of one of the branches of the North lode. This fault-rock consists of a hardened felsitic basis of disintegrated porphyry and slate enclosing angular fragments or partially rounded masses of porphyry, slate, and occasionally jasper—generally angular, and occasionally of considerable size. The bearing of these facts upon the age of the faults is obvious enough.

Apparently the motion of the walls has broken up the porphyries and slates, the latter having been previously metamorphosed into the various forms noted above. In places the fissures must have remained open for a considerable time, while large quantities of fragments fell in and became surrounded by clayey matter.

The Iron-ores.—In a considerable number of places, always on hill-tops, and always near masses of pyrites of greater or less extent, are horizontal beds of iron-ore, consisting of angular or occasionally rounded fragments of quartz, slate, and other rocks, cemented together by peroxide of iron, which is only slightly hydrated.

The proportion of quartz or other matter in these rocks varies from less than 1 per cent. up to 50 or 60 per cent. In a few places these beds have yielded plant-remains, which indicate that they are of Miocene age. It would appear that they were formed at the bottom of lakes—the ferruginous matter having been derived from the decomposition of the pyrites of the upper parts of the lodes—which stood much higher than at present. These beds of ore occur at various elevations, each different level no doubt indicating a period of approximate constancy in the level of the waters, the different beds having been formed as the old lake-boundaries were broken through, and new ones formed at a lower level*.

The following patches of iron-ore of a sedimentary character appear to indicate the former and successive existence in the neighbourhood of the mines, of no new fewer than six ferruginous lakes. The heights given are merely approximate, as determined by a pocket-aneroid. The patches bracketed together appear to have been once continuous, and have been separated by subsequent subaërial denudation.

* The chief of these deposits, that of the Mesa de los Pinos, has been well described by Mr. J. A. Phillips in his paper "On the Occurrence of Remains of Recent Plants in brown Iron-ore," Q. J. G. S. vol. xxxvii. p. 1. He gives the following analysis of a sample of the iron ore from the Mesa, which may be taken as a pretty fair average result for the ore generally exported, except that there are usually present a few per cent. more of silica:—

Water, hygrometric	1·40
Water, combined	11·85
Silica	1·53
Ferric oxide	84·65
Alumina	trace.
Phosphoric anhydride	·14
Sulphur	·23
	99·80

		Above sea-level.			Above sea-level.
1.	Cerro Colorado . .	1794 ft.	4.	Rio Tintillo . .	1370 ft.
	Cerro Salomon . .	1761 „	5.	Los Planes . .	1200 „
2.	Mesa de los Pinos	1500 „		El Lago	1189 „
	Cerro de las Vacas	1497 „	6.	La Naya	1050 „
3.	Bella Vista	1473 „			
	Atalaya	1470 „			

Notwithstanding the geologically recent origin of these ferruginous lake-deposits, they are often traversed by quartz-veins filling shrinkage-cracks, and occasionally small masses of opal (Müller's glass) occur in cavities, showing that there must have been circulation of siliceous waters and deposition of silica in geologically recent times in this district.

In addition to the iron-ore of these hill-top deposits, a very large quantity of excellent iron-ore of precisely similar character has been got out of the "over burden" recently removed from the north side of the great open cast on the South lode. This has, I believe, been formed by the degradation of the ancient bog-iron deposits, and has sunk down over the pyrites into the extensive pre-Roman open workings. These are filled with brecciated masses, consisting largely of fragments of the iron-ore, mixed with slate and porphyry frequently in a state of complete decomposition.

Occasionally the pyrites has decomposed near the surface so as to form a true "gozzan" extending downwards for many fathoms, thus producing a ferruginous substance capable of being used as iron-ore under favourable circumstances, although, as it contains a large admixture of clayey and earthy matters from the sides of the lodes, it is not usually preserved as such. Samples of this ferruginous earthy matter often contain from 35 to 45 per cent. of metallic iron, as shown by analysis.

It is interesting to note that the waters issuing from the mines even now deposit considerable quantities of oxides of iron in the beds of the rivers wherever there are convenient situations. The following are analyses of some of these substances; (H)—yellow ochre from the bed of the Rio Tinto near Manantiales, about 20 miles below the mines; (I)—iron-ore from the Rio Tintillo:—

	H.	I.
Silica and insoluble . .	25·00	13·64
Alumina	2·50	1·06
Ferric sulphate	9·00	
Ferric oxide . . . . (46·80)=hydrate	57·78	73·00
Arsenic	0·27	
Copper	trace.	trace.
Moisture and loss	5·45	12·30
	100·00	100·00

The following may be regarded as typical analyses, (J) of the

natural liquor issuing from the mines, and (K) of the liquor flowing from the cementation-tanks. Each of these is found to deposit iron-oxide wherever the waters are checked so as to allow of natural oxidation and evaporation.

	J. Natural liquor.	K. Salida liquor.	
Ferrous sulphate	4·091	54·276	grams per litre.
Ferric sulphate	·036	6·075	,,
Aluminic sulphate	·504	·800	,,
Manganous sulphate	·003	·016	,,
Zincic sulphate	·308	2·814	,,
Cupric sulphate	1·761	·282	,,
Plumbic sulphate	·009	·040	,,
Calcic sulphate	·259	1·026	,,
Magnesic sulphate	·066	·312	,,
Potassic sulphate	·023	·020	,,
Sodic sulphate	·052	·040	,,
Sulphuric acid (free)	1·274	·752	,,
Sodic chloride	·017	·039	,,
Antimony and bismuth	traces.	traces.	,,
Arsenic	·028	·078	,,
Silica	·074	·026	,,
	8·505	66·596	,,

Pyrites.—The pyrites-masses are almost always contact-deposits, *i. e.* they occupy the enlarged portions of fissures separating two dissimilar rocks. Occasionally, it is true, both walls of a mass are composed of the same rock for a short distance, in vertical or horizontal extension, owing to the fact that the fissure has been made more nearly in a plane than is the bounding-surface of the two rocks, a phenomenon which has been frequently observed in other districts*. Some few of the deposits, however, appear to be contained wholly in slate, and others wholly in porphyry, but never far from a junction of these dissimilar rocks.

The enlarged portions of the pyrites-lodes of Rio Tinto and other parts of the Sierra Morena, it seems to me, only differ in degree from the "shoots" and "courses of ore" observable in connexion with fissure-lodes in other countries. Owing to the lenticular character of the porphyritic intrusions which occupy the original lines of weakness, and which have occasioned those openings which now form the lode-fissures, the junctions between the slate and the porphyry are subject to considerable inflections (see map, Plate VI.); and although the more recent openings which now contain the pyrites have not followed these junctions everywhere exactly, still the result has been to produce fissures somewhat more made up of varying directions than is observable where a simple country-rock has been fissured.

* See Foster "On the Great Flat Lode," Quart. Journ. Geol. Soc. vol. xxxiv. p. 640.

It is obvious that any movement of one side of a fissure which is not a perfect plane, must result in bringing into juxtaposition projecting portions of the opposite walls, in whatever direction the movement may have been; and consequently in forming irregular cavities of greater or less dimensions*.

The cavities having been thus formed, it appears to me highly probable that they have been filled with pyrites by infiltration from the country rocks. Both porphyry and slate are almost everywhere impregnated, and the joints are often lined with pyrites, which invariably contains a trace of copper. The structure of the pyrites masses seems to me to bear out this idea. A somewhat banded arrangement or grain of the pyrites is often visible, running in a longitudinal direction; and frequently portions of the slate, very highly pyritized, have been detached from the walls, and enclosed within the main mass. Owing to the absence of cavities in the pyritous mass, crystals are exceedingly rare, and sometimes it is absolutely compact and structureless.

The "lenticular" deposits of pyrites vary from a few yards up to three quarters of a mile or more in length, and in width from a few inches up to 500 feet. Frequently two or more of these are connected together by a thin vein, almost a thread, of pyritous matter; and they are generally traversed more or less by veins of richer ore, copper-pyrites, copper-glance, galena, &c., and occasionally also of nearly pure iron-pyrites, as well as by veins of barytes and quartz, these latter running in a direction transverse to the general direction of the mass.

Character of the Ore.—As the average copper contents of the ores sent to England only vary between 3 and 4 per cent., I might almost say $3\frac{1}{4}$ and $3\frac{3}{4}$, from year to year, an idea has been generally entertained that the ore deposits as a whole are remarkably uniform in composition. Nothing could be further from the truth, as was shown by the series of specimens sent to the Madrid Exhibition of 1883, which averaged from 20 to 30 lbs. in weight, and contained from 0·5 up to 60 per cent. of copper. The following are the chief varieties of the ores which I have observed:—

a. Poor sulphur-ore; almost pure iron-pyrites, but containing under $\frac{1}{2}$ per cent. each of copper and arsenic. Generally minutely crystalline, but sometimes fine-grained and compact, breaking with an almost conchoidal fracture. Sold as poor ore ("mineral pobre").

b. An ore like *a*, but containing variable quantities of earthy matters, silica, and silicate of alumina, up to 25 or 30 per cent. Valueless ("esteril").

c. A substance like *b*, but distinctly banded in structure, the siliceous matters often rising to 50, 70, or 90 per cent. The pyrites in this substance is generally more distinctly crystallized than in *a* or *b*, the forms being the cube, the pentagonal dodecahedron, or a

* This mode of formation, which is well known to all students of geological mechanics, is very simply explained by De la Beche in his 'Report on the Geology of Cornwall,' &c. p. 317.

combination of the two. Rarely the crystals reach the size of peas, but usually they are minute. This is absolutely valueless ("esteril").

d. A soft powdery or easily pulverized substance, having the same composition as the poor ore *a*, but valueless on account of its powdery condition.

The particles under a lens appear to be crystals. This is known as "azufron." Sometimes the crystals are coated superficially with galena or blende, as if they had been immersed in water capable of depositing those substances.

e. Compact ore like *a*, but containing from 1 to $2\frac{1}{2}$ per cent. of copper, existing as copper-pyrites minutely disseminated throughout the mass. This is the typical "telera mineral," and it is mostly treated on the spot.

f. Compact ore like *e* but richer, up to $3\frac{3}{4}$ per cent. This is the typical exportation ore so largely consumed in the manufacture of sulphuric acid, the copper, and sometimes the silver and gold, being afterwards extracted by "wet" methods.

g. Ore similar to *f*, but coated superficially or in the joints by basic sulphates of copper (brochantite, pisanite, &c.). This is also an exportation ore.

h. Copper-pyrites, erubescite, and occasionally copper-glance, more or less mixed with iron-pyrites, quartz, blende, and other substances, occurring for the most part in veins or veinules traversing the ordinary pyrites. These assay from 4 per cent. up to from 12 to 14 per cent. *en masse*, and are all treated in the blast-furnaces, either raw or previously calcined, as "mineral rico."

i. The same ore, but with much quartz present, reducing the percentage to 3 or 4 per cent. Valuable as a flux in the blast-furnaces ("mineral cuarzo").

j. Mineral like *h*, but very soft and much decomposed. Also remitted to the blast-furnaces, under the name of "negrillo."

k. A compact mixture of galena, blende, and chalcopyrite, mingled with iron pyrites, yielding from 6 to 12 per cent. of lead and the same of zinc, with 3 or 4 per cent. of copper and 2 to 3 oz. of silver to the ton; known as "plomizos," and at present a *bête noire* at the mine. Some of this bears a considerable resemblance to the "bluestone" of Anglesey and to the "kilmacooite" of County Wicklow.

l. The same, but with the lead more differentiated into veins of galena, admitting of dressing or clean hand-picking. There is but little of this ore in the mines.

m. Crystals, stalactites, or stalagmites of cupreous melanterite, containing from 4 to 12 per cent. of copper and from 2 to 10 per cent. of zinc. Often mixed with earthy matter, so that the copper is reduced to from 1 to 3 per cent. This is sent at once to the washing-tanks, under the name of "vitriolas."

n, *o*. Porpyhry and slate, containing grains or veins of iron-pyrites; slightly cupriferous ("esteril").

The varieties *b*, *c*, and *d* appear to reveal much as to their mode of

origin. In *c* we have, I think, the original pyritous schist or mineralized bands of the Palæozoic slate.

The following analyses of the pyrites from different parts of the mines will give a very good idea of the composition of the ores as selected for various purposes, as well as of their freedom from veinstone when well selected. For comparison I add two analyses (P) from a neighbouring mine where the "banded" structure referred to above is very well marked.

	L. Export ore. 1878.	M. Calcination ore. 1880.	N. San Dionisio. 1881.	O. Filon al Norte. 1881.	P. La Majada. Compact.	P. La Majada. Banded.
Sulphur..........	48·98	50·19	47·25	50·00	49·50	37·00
Iron	41·91	42·86	42·35	41·65	40·60	33·00
Copper	3·06	2·29	4·46	2·25	3·62	4·42
Lead	1·47	undeter-	1·26	trace.		
Zinc	0·62	mined.	0·24	trace.		
Copper sulphate ..	0·12	0·20	trace.	trace.		
Oxide of copper ..	0·50	trace.	trace.	trace.		
Arsenic	1·00	0·92	0·61	0·25	0·49	0·47
Antimony	0·06	0·10	trace.			
Alumina, bismuth, manganese, thallium, nickel, cobalt, lime, and magnesia.	traces.	traces.	traces.	traces.	traces.	traces.
Silica and insoluble.	0·28	trace.	2·40	2·62	2·14	22·60
Sulphate of iron ..	0·50	trace.	....	....	....	trace.
Moisture	0·65	0·20				
Oxygen and loss ..	0·73	3·24	1·43	3·23		
	99·88	100·00	100·00	100·00	96·35	97·49

Silver from ½ oz. to 1 oz. per ton in all. Gold from 8 to 11 grains per ton*.

All the above are samples of well-mixed ores. I add opposite a series of analyses of picked specimens, none of them, however, distinctly crystallized. Q is chalcopyrite, of a good yellow colour, soft; R is grey ore, with a good grey colour, and rather harder than usual; S, white pyrites, very light-coloured, a mass of minute crystals, very hard; T is galena, subcrystalline and normal in appearance; U, lead-mineral, fine-grained, grey, and granular.

The pyrites-deposits at Rio Tinto are four in number, known respectively as the North lode, the South lode, the San Dionisio lode, and the Valley lode. Of these, the South lode is that which was worked extensively by the Spanish Government before the mines were taken over by the present Company; it is now chiefly worked as an open cutting. The thin branches or veins seen at

* This small proportion of gold has hitherto resisted all efforts to recover it at a profit, except as regards a small portion of the ore treated at Widnes and in Germany; yet it is worthy of remark that the terreros at Rio Tinto, which we may take in round numbers at 5,000,000 tons, contain more than 2½ tons of gold, reckoning only 8 grains to the ton. The quantity of gold raised annually from the pyrites deposits of the Sierra Morena cannot be less than a ton and a half.

Quebranto Huesos are, I think, connected with the eastern end of the South lode, while San Dionisio may be regarded as an extension westwards of the South lode. This and the North lode have been entirely opened up by the present proprietary, nothing having been done upon them since the Roman times until about the year 1878. The Valley lode is not yet opened up. The North, South, and San Dionisio lodes all show abundant evidence of very extensive work by the Romans, and even of still more ancient works; but as this paper is designed to deal only with the geological and mineralogical features of the district, and not with the mining operations which have been carried on from time to time, or with those which are now being carried on, I need not further refer to these points, except to draw attention to the series of enlarged sections given (figs. 3–8, p. 260), all of which refer to what is known as the South lode*.

	Q.	R.	S.	T.	U.
Sulphur	33·04	24·03	52·81	15·82	40·89
Selenium......	....	....	trace.	0·10	0·13
Iron	34·72	12·21	46·12	2·21	36·24
Copper	31·68	62·50	0·11	0·01	4·30
Arsenic	0·01	0·03	0·23	0·01	0·10
Lead	0·02	0·14	trace.	80·41	11·37
Antimony	....	trace.	...	0·40	0·20
Zinc	0·10	trace.	trace.	0·14	6·66
Bismuth	....	trace.	....	0·21	0·04
Silica and insol..	0·15	0·02	0·10	0·02	0·21
	99·72	98·93	99·37	99·33	100·14
Silver	0·033	0·010	0·005	0·015	0·015
Gold	In all a few grains only to the ton.				

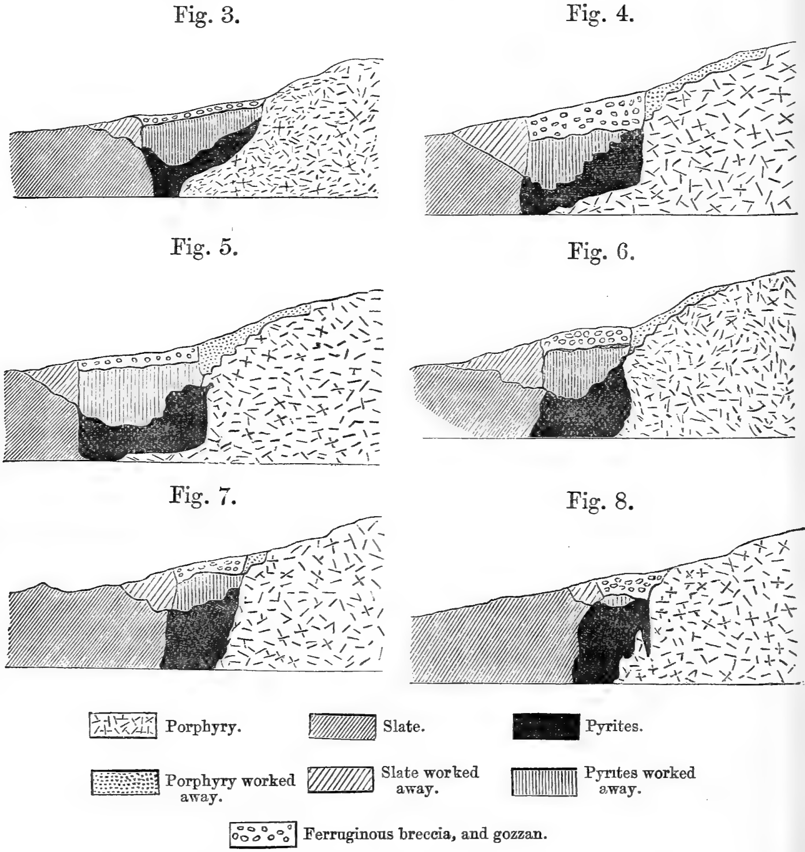
The Manganese-lodes.—A system of fissures having the same general directions as those larger ones which contain pyrites, occurs in the immediate neighbourhood of these latter; indeed, the manganese-fissures often seem to be merely branches of the pyrites-fissures. Like them, they are frequently bounded by slate on one side and by porphyry on the other; but pretty often they have slate on both sides, although they are never found far from masses of porphyry. Occasionally they are entirely in porphyry. The veins vary in width from an inch or less up to several yards. Unlike the pyrites-veins, in which siliceous deposits are conspicuously absent, the manganese-veins are generally very highly silicified, the walls being often converted into excellent jasper to a considerable depth†.

The manganese-ore itself is sometimes very siliceous, but otherwise a fairly pure but hard variety of pyrolusite, assaying over 80 per cent. of peroxide of manganese. A great number of these veins occur in

* A list of the various minerals which have been met with at the Rio-Tinto mines, comprising thirty-three species, is given by me in the 'Mineralogical Magazine,' vol. iv. pp. 211–216.

† An analysis of one of these jasper bands from Bella Vista has been given *supra*, p. 249.

Figs. 3–8.—*Cross-sections of the South Lode at Rio Tinto, showing profiles of the ground removed.* (Scale, 1 to 7500.) Fig. 3. *Section at San-Inocente Shaft.* Figs. 4–8, *respectively* 150, 200, 300, 350 *metres to the East.*

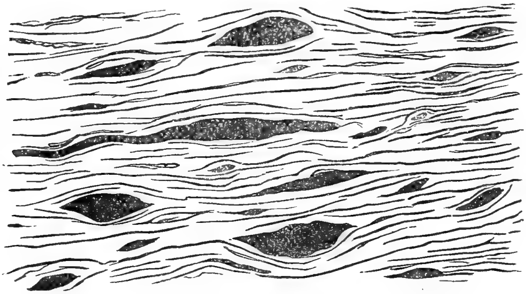


the neighbourhood of Rio Tinto; but at present none of them are being worked, although a great many of them were in active operation some ten years since. The slate in the neighbourhood is generally of a purplish colour; sometimes it contains a series of concretionary kernels or "eyes" of cobaltiferous oxide of manganese, as shown in the sketch (fig. 9), which is taken from a specimen occurring a little to the west of Bella Vista.

In the pyrites-region mineral veins other than those of cupreous pyrites and of manganese are extremely rare and of comparatively little importance. A few veins of lead, copper (oxides, sulphides, and carbonates), of blende, and of other minerals are known to

exist in the quartz-syenite; and some of these could certainly be worked to advantage by Cornish methods if the country were more fully opened up by roads and railways; but I reserve for the present all further reference to them.

Fig. 9.—*Slate with Kernels of Cobaltiferous Oxide of Manganese near Bella Vista.*



4. *Conclusion.*

A consideration of the facts here brought forward leads to the following conclusions:—

1. *As to the Stratigraphy of the District*:—

(*a*) The slates are of late Devonian age, but they include in some places portions of still older clastic rocks, which have not yet been recognized in the neighbourhood *in situ.*

(*b*) The slates, in parts, like the well-known "Kupferschiefer" of Mansfeld, were originally highly pyritous and cupriferous; but being interstratified with ordinary *Posidonomya*-schists, they are plainly much older.

(*c*) After the slates had been deposited and upheaved, they were cut through by great masses of syenite. As this syenite ranges pretty nearly with the present strike of the slate, it is probable that this latter had been folded into its chief synclines and anticlines before the intrusion of the syenite. The slaty cleavage, too, which now corresponds generally, but not invariably, with the bedding, was also produced previous to this intrusion, but may have been since increased.

(*d*) Both slates and syenite have been penetrated by veins and masses of diabase. In the slates the diabase often follows the stratification for considerable distances and then cuts across at a very oblique angle, the mean direction being E. to W. In the syenite no such prevalent direction of the diabase veins is observable.

(*e*) The porphyries are distinctly intrusive in the slates, and not actually interstratified with them, although they often appear to be so. A kind of selective metamorphism has, indeed, converted some

of the stratified beds into a rock resembling the more schistose varieties of the porphyries; but proofs of the distinctness in origin of the porphyritic schists and the schistose porphyries are abundant.

(*f*) The conversion of certain bands of the slates into chert or jasper was anterior to the appearance of the porphyries, since the cherty bands are traversed by them similarly to the slates themselves, and since the "fault rock" contains fragments of the former enclosed within its substance.

(*g*) As the porphyries were intruded into the stratified rocks long after these had been tilted up into their present position (*i. e.* nearly vertical), and as their composition, on the whole, is so similar, it seems not unlikely that they are actually composed of the melted-up lower portions of the synclinal curves.

(*h*) While the porphyries were still in a semi-pasty condition, the pressures in directions normal to the strike probably continued to act, thus producing their markedly schistose structure parallel to the schistose structure of the stratified rocks.

(*i*) The intrusion of the porphyry took place at a period so distant as to allow of immense denudation. We in fact see at the surface what was brought into its present condition at great depth.

2. *As to the Ore-deposits*:—

(*j*) The opening of the main fissures took place along the lines of contact of dissimilar rocks, *i. e.* along lines of least strength.

(*k*) The process of filling-in these fissures was, as regards the pyrites, more chemical than mechanical; but still not entirely chemical. The great width of the fissures in certain places is here, as elsewhere, more apparent than real. On the one hand there seems to have been a great concentration of pyritous matter in solution, probably derived from pre-existing pyritous schists, into the more open parts of the fissures; and on the other a gradual removal, probably by the very same solutions, of much of the earthy matter of the enclosing slates, so as gradually to produce a large mass of very pure ore. The fact that schistose structure is often visible in the interior of great masses of the pyrites appears to me to be in favour of this theory of their mode of formation. The force of crystallization itself, too, may have enlarged the cavities continuously by pressure against the softened wall.

(*l*) That the solutions circulating within the fissures had solvent powers is evidenced by the softening and kaolinization of the rocks in the neighbourhood of the pyritous masses. Silica and lime appear to have been remarkably absent from these solutions; but in the later vein-fillings the former has been deposited to a small extent, and sometimes accompanied by sulphate of baryta.

(*m*) That the fissures were seldom really open to any great extent is, I think, indicated by the rarity of distinct and well-formed crystals of pyrites. At the same time the existence of fault-rock in the immediate neighbourhood proves that open fissures must have existed at one time.

(*n*) The formation of rich veinlets or "leaders" of ore within the masses has been the result of subsequent operations, probably at very many different times. These veins appear to occupy faults and shrinkage-cracks, and to have been gradually filled by a segregation of substances from the main masses of pyrites.

(*o*) Abundant evidence of numerous movements within the masses of pyrites is afforded by the numerous slickensides which are everywhere and continually met with.

(*p*) The formation of the ironstone-beds which now cap the Mesa de los Pinos and other hills, although immeasurably more recent than that of the pyrites-deposits, took place so long ago that deep valleys have since been excavated through the iron-ore; and the general level of the country has been so altered that the ancient lake-deposits now exist as hill-tops.

3. *As to the Surface-Geology*:—

The broad features of the geology of the district, which have been described above, are very evident to any one who has studied the relations between geological structure and scenery. The slate-regions, which for the most part form the lower lands, generally consist of a series of low hummocky hills of a very bare and uninteresting aspect; but occasionally the more silicified bands rise into sharp ridges of a rugged appearance, which, in the transverse valleys, are sometimes extremely picturesque, as in the gorge leading up to the Campo Frio "digue"*. The jasper- and manganese-bands, too, are generally evident as distinctly purple stripes in the otherwise dull lead-coloured country. The barrenness of the slates seems to be due to their vertical condition, to the great and long-continued heats of summer, and to the absence of springs. The vegetation, where there is any, consists generally of the dull dark-green foliage of the gum-cistus. The valleys and watercourses, on the contrary, where the effects of the long summer drought are less felt, are usually filled with oleander bushes, whose abundant pinkish-red flowers mark out the topography in a very striking and beautiful manner. The porphyries are scarcely more clothed with verdure than the slates, but the hills are much higher and more irregular in form, and the ground is generally strewn with rough greyish fragments of the rock. The asphodel, a palmetto, and little scrubby acacias are more frequently to be seen in the porphyry-tracts. The diabase has much richer vegetation, with many olives, oaks, and cork-trees, the surface between the trees being covered with brown and rounded fragments of decomposing diabase, while the rock-exposures are often markedly spheroidal or even columnar. The syenite has a very similar vegetation to the diabase; but the country rock is greyer, and the hills crowned with loose rocks, which often remind one of the granite tors

* At Rio Tinto a reservoir of water, shut into a natural hollow by an artificial wall or bank, is called a "Digue" or a "Dam" indiscriminately, although, of course, the term is only properly to be applied to the enclosing masonry or earthwork.

of Cornwall, but of course without their refreshing green turf-surrounding.

In the immediate neighbourhood of the mines the natural barrenness of the mining part of the Andevallo is greatly heightened by

(1) The destruction of vegetation by the sulphur-smoke from, at Rio Tinto alone, the volatilization of about 200,000 tons of sulphur per annum;

(2) The destruction of brushwood and timber for the use of the mines;

(3) The removal of the unprotected soil by the occasional heavy rains.

The climatal conditions have led to a much more rapid denudation than is observable in countries like England, and it will be readily understood that they have been greatly aided by the temporary conditions noted above.

In the height of summer the surface-rocks of this region are often heated to 160° F., or even more during the day, while the coming of a wind from the north will sometimes reduce the temperature of the same rocks to 70° during the night—a range of at least 90° in perhaps eight or nine hours. These alternations of temperature have, in some cases, caused the scaling-off of thin layers of porphyry, diabase, ironstone-breccia, and other rocks from the more exposed masses on the hilltops and in the broader valleys in a most peculiar manner. I have picked up pieces of the ironstone-breccia measuring at least 8 inches across, with a thickness not exceeding three quarters of an inch. In some spots the rocks have acquired, from this cause alone, rounded forms, which might easily be supposed to result from glaciation, while the flakes of rock cover the ground around to a depth of more than a foot*.

It will be readily believed that disintegration, especially of the schistose rocks, proceeds very rapidly under such conditions as these. Furthermore, in the neighbourhood of the rock-junctions, a great part of the surface-slate, and even the porphyry, is so decomposed as to be commonly used as a kind of fire-clay (*barro*). The occasional heavy rains of spring and autumn, falling upon a ground so prepared, act with extreme energy and produce very marked effects, a single storm sometimes cutting out channels several yards in depth. These facts should be taken into account in forming an estimate of the time required to produce a given amount of denudation, as, for instance,

* The finest example of this "pseudo-glaciation" which I ever saw occurred in the ironstone-breccia lying on the top of the hill a little to the S.E. of No. 4 shaft on the North Lode; and at first I felt pretty sure that here, at least, I had met with a real glacial polishing—the angular pieces of quartz, with their ferruginous cement, were smoothed off so wonderfully. But I soon saw here, as I had seen on other occasions, that there were no ice-scratches and that the apparently polished surfaces met each other in sharp re-entrant angles in such a manner that they could not possibly have been produced by friction. Moreover, the stones were surrounded with bushels of thin flakes of precisely similar character which had peeled off from time to time, some of them being nearly a foot across, with a thickness of considerably less than one inch.

with regard to the relative ages of the successive ferruginous lake-deposits. Greatly as they differ in altitude, it is probable that their difference in age would not exceed a few thousands of years. Unfortunately, however, we have no fossil evidence on this point, since fossils have only as yet been found in the one deposit of the Mesa de los Pinos.

EXPLANATION OF PLATE VI.

Fig. 1. Map of the Rio-Tinto mining district. Scale $\frac{1}{40000}$.
2. Section across the Rio-Tinto mining district. Scale $\frac{1}{40000}$.

Discussion.

Mr. P. Fowler inquired why Mr. Collins attributed the iron-ore forming the outcrop of the pyrites-vein-deposits to the action of lakes. He believed they were due to decomposition of pyrites. With regard to the question whether the deposits of pyrites are to be characterized as veins or masses, he believed them to be veins, as they never cut out in depth; they often narrow, but open out again. Mr. Collins had omitted to notice that all the veins crop out in great depressions, due, probably, to enormous faults. The greater the depression the greater the width of the vein.

Mr. Kitto agreed with Mr. Collins as to the iron-ore deposits being lacustrine in their origin. They were stratified, and contain the remains of plants. He also was inclined to class the masses of pyrites at Rio Tinto as veins.

27. *On the* Geological Position *of the* "Weka-pass Stone" *of* New Zealand. By Captain F. W. Hutton, F.G.S. (Read June 25, 1884.)

The northern part of Ashley County, in the Province of Canterbury, is, to the geologist, one of the most interesting districts in New Zealand; for, as Dr. von Haast has truly remarked, it "offers us the key to unravel the relations in which our young Secondary and old Tertiary beds stand to each other." And as all the more important of the New-Zealand coalfields belong to one or other of these groups of rocks, the district becomes highly important from an economic point of view.

The district in question is bounded on the north by the Hurinui River and on the south by the Waipara River, so well known to geologists as the locality whence *Plesiosaurus australis*, Owen, was obtained by Mr. Cockburn Hood. It is crossed by the railway and road from Christchurch to Nelson, which here pass over a low range of hills by means of a depression called the Weka Pass, which gives the name to the limestone that forms the subject of this paper. In it there occurs a white, flaggy, argillaceous limestone, known as the Amuri limestone, which at both the Waipara River and Weka Pass lies conformably on green sandstones. All geologists who have visited these localities agree that the Amuri limestones and the green sandstones are parts of the same rock-system, which is called the Waipara System by Dr. von Haast and myself, and forms part of the Cretaceo-tertiary System of Dr. Hector and the officers of the Geological Survey of New Zealand. This Waipara System is considered to be of Cretaceous age, because the green sandstones contain remains of marine Saurians and rest conformably on beds of coal and shales, containing leaves of dicotyledonous Angiosperms, that form the base of the Waipara System.

Above the Amuri limestone, both at the Waipara and Weka Pass, comes an arenaceous limestone, usually with small green grains scattered through it, called the Weka-pass Stone. It is of a yellowish white colour, but weathers white like the Amuri limestone. Above the Weka-pass Stone is a grey sandy marl, and above this, again, come thick beds of pale yellowish sandstone, with bands of shelly and coral limestone. These last beds, lying above the grey marl, are acknowledged by all New-Zealand geologists to be, probably, of Upper Eocene or Oligocene age. They are the Mount-Brown beds of the Geological Survey, and form the upper part of the Oamaru System of Dr. von Haast and myself.

So far all are agreed; but opinions differ as to where the line separating the Waipara System from the Oamaru System should be drawn. Dr. Hector and Mr. M'Kay think that it should be taken between the Grey Marl and the overlying Mount-Brown beds; Dr. von Haast would make it between the Weka-pass Stone and the

Grey Marl; while in my opinion it lies between the Amuri limestone and the Weka-pass Stone. On this point Dr. Hector says that he cannot satisfy himself "of any stratigraphical break between the Amuri limestone and the overlying grey marls" *, apparently placing the Weka-pass Stone with either one or the other. Mr. M'Kay says, "No doubt there is a considerable difference in the character of the fossils found in the calcareous green-sands [*i. e.* Weka-pass Stone] and those in the underlying Saurian beds; but, even admitting the conformity between them, this is to be expected. Stratigraphically, I could find no conclusive evidence of unconformity, and if the Weka-pass calcareous green-sands belong to the Waipara beds, no unconformity can be conceded as far as the uppermost beds of the Mount-Brown Series" †. Dr. von Haast says that in the northern parts of Canterbury the green sandstones of the Waipara are overlain by "chalk marls, or chalk-like limestone" [*i. e.* Amuri limestone], which is succeeded by a glauconitic calcareous sandstone [*i. e.* Weka-pass Stone], and which is the highest bed of the series ‡. He allows that a break sometimes, as at Weka Pass, appears to occur between these two calcareous rocks; but he argues that this is only apparent, because the upper beds are always conformable to the lower, and in some localities there is a gradual passage from the one to the other. He does not, however, name these localities.

Such are the views held at present by those geologists who have visited the district. The object of this paper is to bring together all available evidence on the position of this divisional line. But before doing so it will be better to give the geographical distribution of the beds with which we are concerned.

Geographical Distribution of Rocks.

The *green sandstones* and other associated rocks with acknowledged Cretaceous fossils extend from near Cape Campbell, on Cook's Straits, along the east coast of the island, to the Hurinui, and then trend inland to the Middle Waipara and the Malvern Hills, lying between the Waimakariri and Rakaia rivers. In no other part of New Zealand are they known with certainty, and in no other part have any Cretaceous marine Saurians been found. The *Amuri limestone* occurs near Cape Campbell, and going southward, is found at various places along the east coast as far as Motunau, and again at Weka Pass and the Middle Waipara. Further to the south it is quite unknown, except possibly in the Trelissic basin on the Waimakariri §. In the North Island it has been recognized by Mr.

* 'Geological Reports,' 1873–74, p. x. Published in 1877.

† 'Geological Reports,' 1874–76, p. 39. See also Trans. N. Z. Institute, ix. (1876) p. 583.

‡ 'Geology of Canterbury' (1879), p. 297.

§ The chalk-marls mentioned by Mr. M'Kay at Kakahu and Pareora, in South Canterbury (Geol. Reports, 1876–77, p. 61), appear to be different. Dr. von Haast considers them, correctly I think, as belonging to the Oamaru System (Geol. Canterbury, p. 309).

M'Kay at White-rock station on the east coast of Wellington. At Amuri and Kaikoura this rock contains flints. The *Weka-pass Stone* is largely developed in the Weka-pass district between the Waipara and the Hurinui, and it forms a large part of Mt. Cass. North and south of these rivers it is not certainly known, but it is generally thought to be the equivalent of the "Ototara Stone" of Oamaru, and of the Cobden limestone of Greymouth. The *Grey Marl* * extends north from the Waipara through Weka Pass, Motunau, Conway River (?), Amuri Bluff, Kaikoura Peninsula, and perhaps to Cape Campbell. The *Mount-Brown beds* are well developed through the Weka-pass district; but beyond this their extension is uncertain, although no doubt they have equivalents in many parts of New Zealand, principally in the south.

It will thus be seen that the country between the Waipara and the Hurinui is the only district in which all five rocks can be seen together. The Saurian beds, the Amuri limestone, and the grey marl extend to the north as far as Cook's Straits. But the Weka-pass Stone and the Mount-Brown beds do not follow them, but find their equivalents more in the south. I will now examine the geological relations between them.

Stratigraphical Evidence.

Middle Waipara.—Dr. Hector reported, in 1869, that "white and yellowish calcareous sandstones [*i. e.* Mount-Brown beds] rested unconformably on the lower rocks" †. He did not distinguish between the Grey Marl, the Weka-pass Stone, and the Amuri limestone, but considered them all as a "blue-grey marly sandstone sometimes passing into chalk." Subsequently Dr. von Haast divided these rocks into a "Weka-pass Series" [including the Amuri limestone and the Weka-pass Stone], "Cucullæa-beds" [*i. e.* Grey Marl], and "Mount-Brown Series" ‡. He agreed with Dr. Hector that an unconformity existed between the Mount-Brown beds and the Grey Marl, and made another unconformity between the Grey Marl and the Weka-pass Stone. In 1873 I distinguished the Amuri limestone from the Weka-pass Stone, showing that the latter passed at its base into a thin layer of calcareous green sandstone, which rested on a water-worn surface of the Amuri limestone. I also pointed out that the apparent unconformities were deceptive, and due to a fault (fig. 1); and that in reality the Weka-pass Stone,

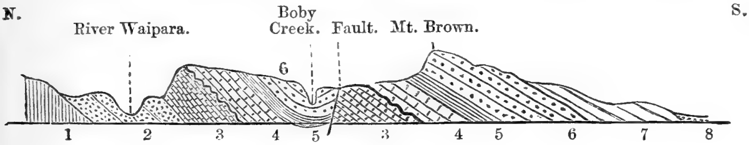
* Called "Leda-marls" by Dr. Hector (Trans. N. Z. Inst. vi. (1873), p. 356), and by Mr. M'Kay (Geol. Reports, 1874–76, p. 178). This name has been applied to various rocks in widely separated localities in New Zealand. Dr. Hector now puts the "Leda-marls" as the equivalent of the Amuri limestone (Geol. Reports, 1877–78, p. 193), and makes it quite distinct from the grey marls of Weka Pass and Amuri Bluff; as also does Mr. M'Kay in the Trans. N. Z. Institute, ix. (1876), p. 583. The so-called "Leda-marls" of Raglan and the Lower Waikato, are probably of about the same age as the Weka-pass Stone. Under these circumstances, I think it is better not to use the name.

† 'Geological Reports,' 1868–69, p. 12.

‡ 'Geological Reports,' 1870–71, p. 14

the Grey Marl, and the Mount-Brown beds were all conformable *. This explanation of the district has not since been called in question by any one.

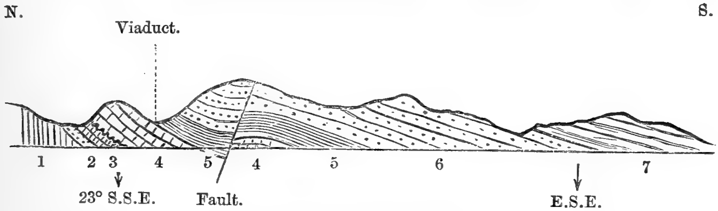
Fig. 1.—*Section across the River Waipara.* (Distance 6 miles.)



1. Hokanui Sandstone.
2. Green Sandstones. } Waipara System.
3. Amuri Limestone. } Waipara System.
4. Weka-pass Stone.
5. Grey Marl.
6. Mt.-Brown beds. Oamaru System.
7. Pareora System.
8. Pleistocene gravels.

Weka Pass.—In my report of 1873, just mentioned, I said that here, as at the Waipara, the Weka-pass Stone rested on a water-worn surface of the Amuri limestone. As the correctness of this statement has been denied, I again visited the locality last December, but found no reason to alter my former opinion. The great masses of limestone which are seen on the west side of the road in the centre of the pass, and on both sides near the northern end, belong to the Weka-pass Stone. The Amuri limestone hardly shows in the pass, but is exposed in a cutting made by the Weka Creek, a little to the north of the railway-viaduct (fig. 2), where both railway and road cross the stream, about a mile and a half from the north end of the pass, or two miles and a half from the Waikari railway-station. Here the

Fig. 2.—*Section along Weka Pass.* (Distance 4 miles.)



For explanation see fig. 1.

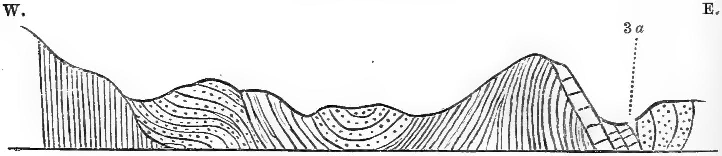
stream has cut a small gorge on the east side of the railway and parallel to it, in which the junction between the two rocks is clearly exposed. This is, I believe, the only section in the neighbourhood in which the actual junction of the two rocks can be studied. Both rocks have here the same dip, but they are easily distinguished. The Amuri limestone is a white, rather argillaceous, much-jointed limestone, in thin parallel beds, and the exposed surface has in consequence a shattered appearance. The Weka-pass Stone is a pale

* 'Geological Reports,' 1873–74, p. 44 (published in 1874).

yellow or whitish arenaceous limestone with scattered green grains, which get more abundant near the base but are never sufficiently numerous to give it a green colour. The exposed surface is honeycombed, thus strongly contrasting with that of the Amuri limestone. A close inspection shows that the upper surface of the Amuri limestone is much broken and fissured, the Weka-pass Stone penetrating into the fissures for a distance of one or two feet, with an abrupt division between the two rocks. Also rounded pebbles of the Amuri limestone are found in the Weka-pass Stone within six inches of the junction, but not higher. These pebbles are not concretions, as has been supposed, for they are exactly similar in composition and structure to the Amuri limestone on which they lie, and are quite different in appearance from the concretions found in the green sandstones underlying the Amuri limestone. Evidently we have a waterworn surface, and therefore, as the nature of the upper rock excludes the idea of chemical erosion, we have an unconformity. In addition to this the Weka-pass Stone overlaps the Amuri limestone to the north and rests on the slate rocks of Mt. Alexander at Hurinui; and as neither rock is a shallow water deposit, and as the Amuri limestone extends far north of the Hurinui, this overlap is another proof of unconformity. Overlapping is also seen in other places as mentioned in my report previously alluded to.

Motunau River.—I have not examined this section myself, but Mr. M'Kay says, that near the north-east part of Mt. Cass range there is a syncline, in which the Grey Marl is seen overlying the Amuri limestone (fig. 3). On the west side of this syncline the

Fig. 3.—*Section across the South Branch of Motunau Creek (after M'Kay).*



For explanation see fig. 1.

Grey Marl, containing here *Pecten Zittelli* *, rests unconformably on the lower beds of the Waipara System, while it passes upwards into the Mount-Brown beds †. Nevertheless, Mr. M'Kay thinks that this apparent relation of the Grey Marl to the Mount-Brown beds is not real, because more to the north-east the Grey Marl is interbedded with the upper portion of the Amuri limestone ‡;

* *Pecten Zittelli,* Hutton, is the same as the *Pecten* belonging to the group *Pleuronectes,* in the palæontology of the voyage of the 'Novara,' pl. ix. f. 3.

† 'Geological Reports,' 1879–80, p. 113.

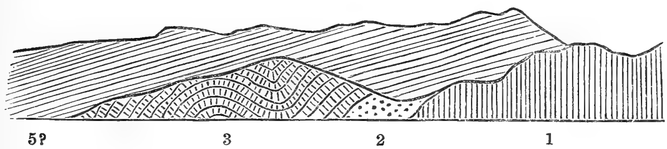
‡ His section, however, shows the Grey marl as unconformable on the Amuri limestone, as well as on the older Waipara beds (see fig. 3), and at 3*a* the Amuri limestone is unconformable on the Waipara beds.

"which," he says, "must convince any one that the conformity to the Mount-Brown beds in the south-west branch of the Motunau River is only apparent." I confess that I cannot follow this reasoning. It seems to me that these sections, if they are correctly interpreted, show an unconformity between the Amuri limestone and the lower beds of the Waipara System, and a regular sequence from the Amuri limestone into the Mount-Brown beds, *although the Weka-pass Stone is absent.* But probably Mr. M'Kay has here mistaken the Weka-pass Stone for the Amuri limestone, a very easy mistake to make; and if this is the case his sections will agree with those in other localities.

Stonyhurst.—This place is on the sea-coast, a little south of the mouth of the Hurinui. Here the Amuri limestone is overlain by a grey sandstone, probably the representative of the Weka-pass Stone. Between the two rocks is a bed of conglomerate formed by sub-angular pebbles of slate. At first sight all three appear to belong to one system; but a close inspection shows that the surface of the limestone is fissured, and that the sandstone penetrates through the conglomerate into the fissures of the limestone. This, however, may be due to chemical erosion.

River Conway.—Some ten or twelve miles from the mouth we again get an excellent section in the bed of the river (fig. 4). Here

Fig. 4.—*On the South Bank of the Conway River.*
(Distance $\frac{1}{4}$ mile.)



For explanation see fig. 1.

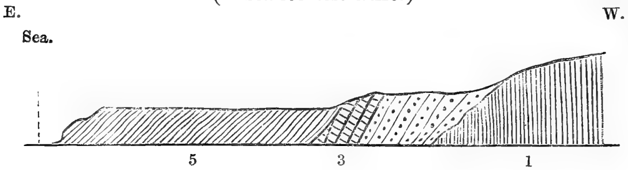
the Amuri limestone is seen to be somewhat folded, and overlain quite unconformably by a bed of blue marl passing upwards into pale yellow sandstone *. As will be seen later, the fossils found in this marl make its age rather doubtful. I believe it to be the same as the Grey Marl of the Weka Pass, but it may be younger. Dr. von Haast says of this section, "The lowest limestone layers have been deposited without disturbance, but seem afterwards, on the western side, to have been folded up in a most remarkable manner, after which newer beds of the same rock have again been deposited, reposing unconformably upon the lower beds. This fold does not occur on the opposite, eastern, side, but the unconformity between the upper and lower beds exists there also" †. The fossils, however, show that the upper rocks are much younger than the Amuri

* 'Geological Reports,' 1873–74, p. 48.
† 'Geological Reports,' 1870–71, p. 40.

limestone upon which they rest, and the unconformity therefore is not due to local causes, but is the result of a general denudation.

Amuri.—Here we get another section showing the Amuri limestone covered by the Grey Marl (fig. 5). Dr. von Haast thinks that

Fig. 5.—*Section through Amuri South Bluff.*
(Distance one mile.)



For explanation see fig. 1.

the Grey Marl (called Leda-beds) has, at the South Bluff, been deposited in sequence on the Amuri limestone *; but he makes a difference in the dip of the two rocks. For in his section he shows the limestone dipping E. 70°, and on p. 38 of his report he says that the Grey Marl dips S.E. 48° to 22°. At the same locality I found, like Dr. von Haast, that the Amuri limestone dipped E. 70°, and that the Grey Marl in contact with it dipped E.S.E. 45°, gradually changing to S.E. 15°; thus indicating an unconformity, although the actual junction of the two rocks was not seen.

According to Mr. M'Kay, a bed of "green-sand conglomerate" comes between the Amuri limestone and the Grey Marl, which he supposes to represent the Weka-pass Stone †. He has no doubt that all are conformable and belong to one system, but he makes the Amuri limestone to dip E.S.E. 45° ‡, and the Grey Marl to dip S.E. 45° to 15°. He also shows that the Amuri limestone thins out in a distance of about a mile, from 630 feet at South Bluff to 330 feet at Amuri Bluff, while the underlying beds belonging to the Waipara System retain their thickness, or even get thicker §. In a bed of argillaceous limestone with flints, which extends from the Waipara to Cape Campbell, this rapid local thinning in the middle of its length looks much like the result of denudation.

No fossils had been described from the Grey Marl at this locality when I wrote my report, and I placed it in the Pareora System (Miocene) because the rocks in the Conway were supposed to be of that age. Since then Dr. Hector has found *Pecten Zittelli* and other fossils in it which would make it probably the same bed as the Grey Marl of the Weka Pass.

* 'Geological Reports,' 1870–71, p. 37.

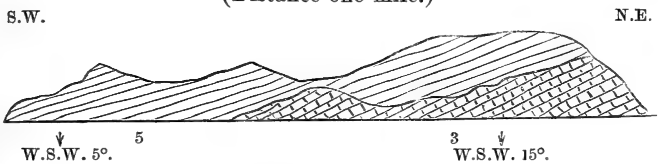
† This is the "Fucoidal limestone" of Dr. Hector (Geol. Reports, 1873–74, p. xi), which he places below Weka-pass Stone (Geol. Reports, 1877–78, p. 192). Mr. M'Kay obtained bones of *Palæeudyptes antarcticus*, Huxley, from it.

‡ Judging from this dip Mr. M'Kay appears to consider as Amuri limestone the same beds that I consider to be Grey Marl; and this may account for his statement that *Pecten Zittelli* occurs in the former rock.

§ 'Geological Reports,' 1874–76, p. 178.

Kaikoura Peninsula.—This is perhaps the most satisfactory of all the sections along the coast, as both the Amuri limestone and the Grey Marl are clearly exposed in sea-cliffs, especially at the eastern end of the peninsula. Dr. von Haast gives sections, running east and west from East Head, showing the Grey Marl (called *Scalaria*-beds) resting quite unconformably on the limestone, and he describes the marl as much younger than the limestone and often unconformable to it *. In my report (1873) I gave a section of East Head (fig. 6), running in a north-east and south-west direction,

Fig. 6.—*East Head of Kaikoura Peninsula.*
(Distance one mile.)

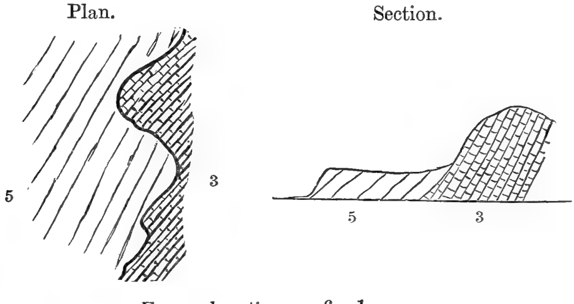


For explanation see fig. 1.

which is merely a sketch of the cliffs as seen from the sea, and which quite confirms the opinion of Dr. von Haast. Dr. Hector, however, denied the correctness of these reports, and Mr. M'Kay subsequently gave a section showing the two rocks apparently conformable †, but in his report he makes no allusion to the subject, and does not even mention his section.

The true position of the beds is, however, quite clear and unmistakable by any one who will walk round East Head. But as further evidence may be necessary, I give from my note-book the plan and section of a junction, a few yards long, between the two rocks, as seen on the sea-beach on the south side of the peninsula (fig. 7).

Fig. 7.—*On South Beach of Kaikoura Peninsula. Plan and Section showing junction of Amuri Limestone and Grey Marl.*



For explanation see fig. 1.

* 'Geological Reports,' 1870–71, p. 43; sections vii. and viii.
† 'Geological Reports,' 1874–76, p. 170; section A A.

No fossils have been found in the Grey Marl here, but no doubt it is the same rock as the marl at Amuri Bluff, about 13 miles distant.

Conclusions.—The following conclusions can, I think, be fairly drawn from the evidence:—

1. The sections at Waipara, Weka Pass, and Motunau River all show that the Grey Marl passes up conformably into the Mount-Brown beds; and these are the only described sections in the whole of New Zealand where the relations between these two rocks can be studied.
2. At the Motunau River the evidence is clear that an unconformity exists somewhere between the Grey Marl and the lower beds of the Waipara System.
3. At Kaikoura Peninsula (and probably at Amuri Bluff and River Conway) the evidence is clear that the break is somewhere between the Grey Marl and the Amuri limestone.
4. At Waipara and Weka Pass the Grey Marl passes downwards conformably into the Weka-pass Stone. The same is probably the case in the Motunau River; and these are all the described sections in New Zealand where the relations between these two rocks can be studied.
5. At Waipara and Weka Pass (and probably at Stonyhurst) the Weka-pass Stone rests on a waterworn surface of the Amuri limestone. In the Weka-Pass district the Weka-pass Stone overlaps the Amuri limestone, and Mr. M'Kay's section of the Motunau River probably shows that it rests unconformably on the lower beds of the Waipara System.

Consequently the break in the succession must be between the Weka-pass Stone and the Amuri limestone.

Palæontological Evidence.

As it is necessary to restrict ourselves to the described fossils that have been found in the district included in the sections, and not to take in any from supposed equivalents of the rocks elsewhere, the palæontological evidence is limited.

The *Amuri limestone* is almost unfossiliferous, at any rate it contains no characteristic fossils, but it is always associated with underlying rocks containing remains of marine Saurians and Mesozoic Mollusca. Mr. M'Kay says that at Amuri Bluff it contains the same fossils as the Grey Marl *, but the only evidence of any value that he gives is the finding of *Pecten Zittelli*, Hutton, in the Amuri limestone. I have already hinted that this shell may have come from the Grey Marl, where it was found by Dr. Hector; but if its occurrence in the limestone should be confirmed, it would merely lessen the value of *P. Zittelli* for correlating rocks; as this species passes up into the Pareora System (Miocene).

* Trans. N. Z. Institute, ix. (1876), p. 583.

In the *Weka-pass Stone* the following fossils have been found:—Bones of Cetaceans, *Voluta elongata*, Hutton, *Scalaria rotunda*, Hutton, *Struthiolaria senex*, Hutton, *Pecten Hochstetteri*, Zittel, *Meoma Crawfordi*, Hutton, *Schizaster rotundatus*, Zittel, and *Flabellum circulare*, Tenison-Woods. All these are also found in other parts of New Zealand in beds generally admitted to be of Upper Eocene age; and Dr. Hector even mentions *Struthiolaria senex*, *Pecten Hochstetteri*, and *Meoma Crawfordi* as characteristic of the Upper Eocene rocks *. *Pecten Hochstetteri* passes up also into the Pareora System, and *Flabellum circulare* into the Pliocene beds of Shakespeare's Cliff at Wanganui, in Wellington Province. None of them are known from the Waipara System †. The palæontological evidence is therefore altogether in favour of the Weka-pass Stone belonging to the Oamaru System.

In the *Grey Marl*, Dr. Hector has found *Pecten Zittelli* in the Weka Pass ‡ and at Amuri Bluff, and Mr. M'Kay has found it at Motunau River together with *Dentalium tenue*, Hutton. *Flabellum laticostatum*, Tenison-Woods, has been obtained from the Weka Pass. All these fossils occur in other places in rocks belonging to the Oamaru System. *Pecten Zittelli* was originally figured by Zittel from rocks which both he and Dr. von Hochstetter considered as Oligocene or Upper Eocene. None of them are known from the Waipara System unless *P. Zittelli* extends into the Amuri limestone. The Grey Marl must therefore be placed in the Oamaru System.

From the marl in the Conway River have come *Natica solida*, Sow., *Solenella australis*, Quoy and Gaimard, *Solenella*, *Salicornaria immersa*, Tenison-Woods, *Scolangia parvisepta*, Tenison-Woods, and *Balanophyllia alta*, Tenison-Woods. Of these *Solenella australis* is still living, and *Natica solida* is common in the Pareora System. It has also been obtained in the Weka Pass, but from which rock is unknown. There is nothing here to connect this bed with the Grey Marl at Weka Pass and at Amuri Bluff, and its age must for the present remain doubtful.

The palæontological evidence is therefore decidedly in favour of the Weka-pass Stone and the Grey Marl belonging, with the Mount-Brown beds, to the Oamaru System. The Amuri limestone is allowed by all to belong to the Waipara System, but as it is almost unfossiliferous, there is no palæontological evidence as to its proper place. It is, however, always associated with rocks of admitted Cretaceous age; while beds containing the same fossils as those from the Weka-pass Stone are found in many places in New Zealand from which no rocks containing generally admitted Cretaceous fossils are known §. Consequently the palæontological break must be be-

* 'Geological Reports,' 1878–79, p. 76; and 'Handbook of New Zealand,, 2nd ed., 1883, p. 28.

† Such is my impression. The Cretaceous Mollusca of New Zealand have not yet been described.

‡ 'Geological Reports,' 1873–74, p. 10.

§ The following are examples:—Lower Waikato District in Auckland, Golden Bay in Nelson, Brighton on the west coast of the South Island, the south-eastern portion of the Canterbury Province, Oamaru in Otago, and Winton in Southland.

tween the Amuri limestone and the Weka-pass Stone, exactly where the stratigraphical evidence places it.

In his 'Progress Report of the Geological Survey of New Zealand' for 1881 (p. xxii), Dr. Hector has given his reasons in favour of a Cretaceo-tertiary System, and I gladly reproduce them so that both sides of the case may be taken into consideration. He says, "The objections which have been suggested against the present classification appear to rely for substantiation on the fact that the fossils of certain localities are not in every respect those found in other localities, and thus, while the Cretaceous age of the beds in some districts is not disputed, in other localities the coal series, although lithologically the same in character, and closed by beds acknowledged to be the equivalent of those terminating the admittedly Cretaceous rocks, are, on account of a more Tertiary aspect of their fossils, pronounced to belong to a younger formation. In Northern Canterbury, as far south as the Rakaia River, the coal rocks are overlain by fossiliferous strata, which, besides the Plesiosauroid reptiles for which the Waipara district is famous, contain a few Secondary genera, such as *Belemnites*, *Aporrhais*, *Inoceramus*, and *Trigonia*; but the great mass of the associated molluscan fauna agrees with that of the coal rocks in other parts of New Zealand, where the specially Cretaceous forms are rare or absent from the fossiliferous horizons immediately overlying the coal-seams. If, therefore, after eliminating the comparatively few fossils which form the peculiarities of two localities, the bulk of those remaining are found to be the same, there need be no hesitation in considering strata showing the same succession of like characters in its different divisions as belonging to the same series; and, if in any one of these localities there is evidence that the beds are of Cretaceous age, the other must be regarded as of that age also. But if, in addition to this, there be, in those localities where the lower beds lack fossils proving their Cretaceous age, a presence of Cretaceous forms in the higher beds of the same series, the correctness of the correlation will in this way be corroborated. It is partly by evidence of this kind that the Cretaceous age of several of our coal-bearing areas is sought to be established."

But in this argument there is, I venture to think, a fallacy. It is no doubt true that the coal of the Waipara is overlain by green sandstones and calcareous rocks of Cretaceous age, and that these are again overlain by other calcareous rocks containing fossils of Tertiary aspect, such as *Pecten Hochstetteri* and *P. Zittelli*. But it is not acknowledged that these latter terminate the Cretaceous rocks. On the contrary it is asserted that they form a distinct series, separated physically and palæontologically from the Cretaceous System, and belonging to an Oligocene System. Consequently it is not admitted that the great mass of the Molluscan fauna associated with marine Saurians at Waipara "agrees with that of the coal-rocks in other

parts of New Zealand." For this statement can only be supported by taking the fossils of the Weka-pass Stone and the Grey Marl, together with their equivalents in other parts of the colony, such as the Ototara and Cobden limestones, as belonging to the Waipara System. I judge this to be Dr. Hector's meaning, because a little further on he says, "The Cretaceous character of the Echinodermata found in the Cobden limestone, also present in the Ototara stone, warrants the reference of these beds to a period anterior to that of any Tertiary deposit in the islands, the oldest of which is at least [? most] Middle Eocene, and separated by unconformity from the underlying beds." But passing over the Tertiary Mollusca associated with these Echinodermata, I cannot admit the Cretaceous character of the Echinodermata themselves. Up to the present, six species have been described from the Cobden limestone, belonging to the genera *Macropneustes*, *Eupatagus*, *Meoma*, and *Schizaster*. It was with reference to these very fossils that I wrote in 1873, in the introduction to the 'Tertiary Mollusca and Echinodermata of New Zealand,' that "an examination in the field of the Culverden beds * showed me that these also must be transferred to the Ototara group, and the Weka-pass building-stone to the lower part of the same formation. This necessitated the transference of the Cobden limestone also into this formation, *thus eliminating from the Waipara formation most of its Tertiary-looking fossils*." It must also be remembered that *Pecten Zittelli* occurs in the Cobden limestone.

As the Mollusca of the Waipara System have not yet been described, I may be mistaken; but my impression is, after looking over the collections in the different Museums, that if the line between the Waipara and Oamaru Systems be taken immediately above the Amuri limestone, hardly any species of Mollusca, perhaps not a single one, will be found on both sides of it; whereas if it be drawn anywhere above the Weka-pass Stone there must always be a large number of species found on both sides of it.

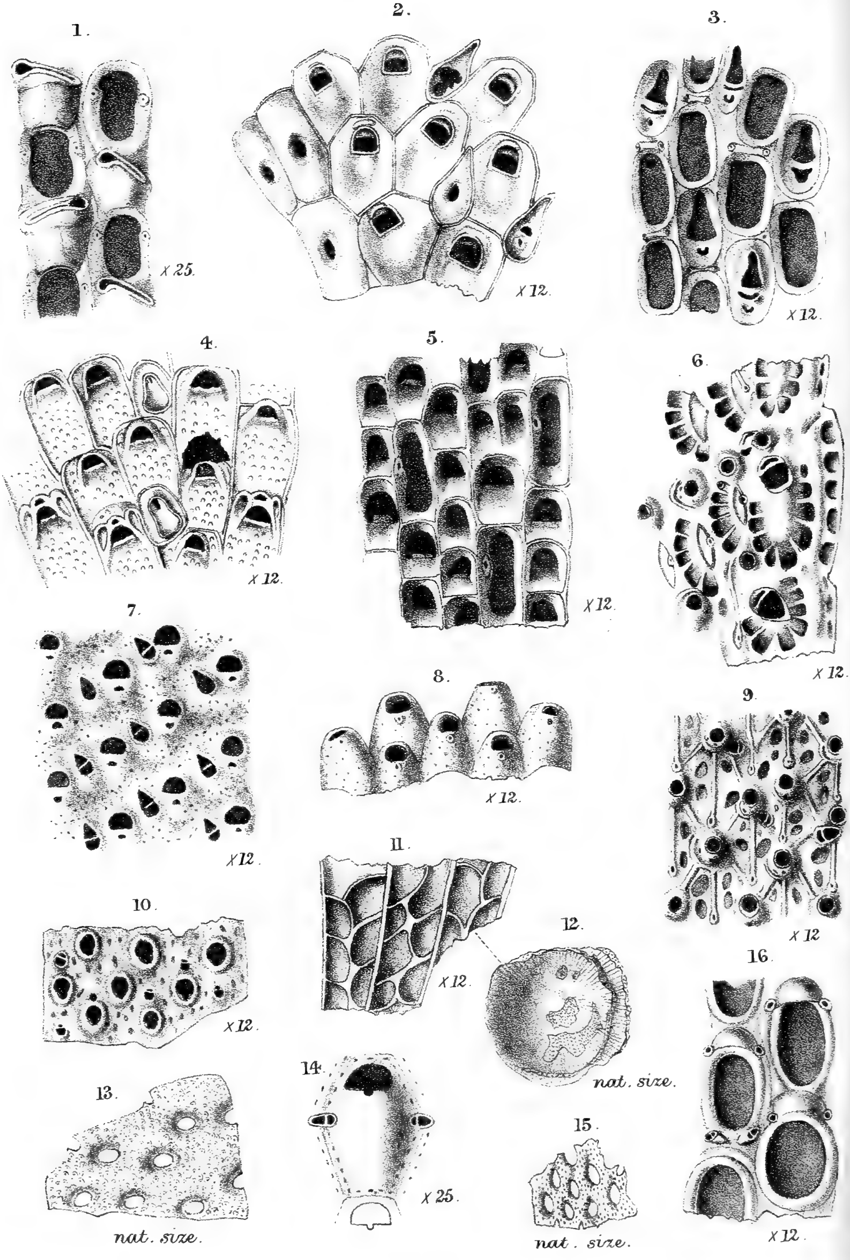
I have already stated that no characteristic fossils have been described from the Amuri limestone itself, and consequently an equivalent in any other part of New Zealand can only be demonstrated at present by showing that it contains fossils characteristic of the other beds of the Waipara System, or that it rests conformably on beds containing such fossils; and in the latter case the proof would not be conclusive, as the Oamaru System might appear conformable in some places to the Waipara System.

Again it is true that the Coal at Whangarei and the Bay of Islands, in the Province of Auckland, is overlain by green sandstones and limestones containing *Pecten Hochstetteri*, *P. Zittelli*, &c., and that all belong to one system. But it is on the assumption that the coal and green sandstones at these places are of the same age as the coal and green sandstones at the Waipara, that the argument is based for considering the beds containing fossils of Tertiary aspect to belong to a Cretaceo-Tertiary System. But lithological resem-

* Called Jurassic by Dr. von Haast and Prof. M'Coy, Geol. Reports, 1870–1871, p. 29.

blances can have no weight when opposed to palæontological evidence, especially when the localities are 450 miles apart. And if it has been proved that there is a break in the Weka-pass district between the Cretaceous beds and those containing Tertiary fossils, then the coal and green sandstones at Whangarei must be referred by their fossils to a Tertiary and not to a Cretaceo-Tertiary System.

So long as these fossils are assumed to belong to a Cretaceo-Tertiary System, so long will Dr. Hector be right in saying that "the classification of our Lower Tertiary and Upper Cretaceous deposits is a problem of considerable difficulty." But let the line of division be taken where the sections in the Weka-pass district show it to exist, and I think the problem will be found capable of an easy solution.



A.W.Waters del. A.T.Hollick lith. Mintern Bros. imp.

SOUTH-AUSTRALIAN CHILOSTOMATOUS BRYOZOA

28. Chilostomatous Bryozoa *from* Aldinga *and the* River-Murray Cliffs, South Australia. By Arthur Wm. Waters, Esq., F.G.S. (Read February 25, 1885.)

[Plate VII.]

The fossils described in the present paper were collected by Professor Ralph Tate, who kindly sent them over to me for description. With a few exceptions, they are from Aldinga, or the "River-Murray Cliffs." A few small and imperfectly preserved specimens are from a bore-hole in Adelaide, representing a find which seems to have considerable geological interest. They are evidently from a clay matrix, and belong to species common in the clay of Curdies Creek. The collection furnished various Cyclostomata, which have already been dealt with in a former paper (Quart. Journ. Geol. Soc. vol. xl. p. 674).

As a considerable number of Australian fossil Chilostomata have already been described, we naturally find many old friends; but there are also several new forms of extreme interest, especially as bearing upon the question of the various modes of growth of the Chilostomata. The previous collections have furnished a large number of instances of a species growing in both Eschara- and Lepralia-forms, and we again find new examples of this, among which *Membranipora rhynchota*, Busk, in the Eschara stage, is especially interesting; and there are examples of already-known *Smittiæ* and *Monoporellæ* occurring in a reticulate form; but this time the chief interest is in a number of specimens which grow in a cupulate manner, which we might either call Cupularia- or Lunulites-form, and for convenience we will adopt the latter. There is *Lepralia edax* in this form; a *Microporella* for which the name *pocilliformis* is proposed; and, further, a second *Microporella*, which was named by Mr. Tenison-Woods *Lunulites magna*; also *Membranipora aperta*, Busk, in this form. We are already acquainted with *Cumulipora transilvanica*, Rss., which is a *Microporella* growing in a solid form. *Stichopora clypeata*, Hag., and *Lunulites Goldfussi*, Hag., are both Membraniporidæ; *Cellepora crustulenta*, Hag., has zoœcia similar to those of *Selenaria maculata*, Busk; *Lunulites incisa*, Hincks (*Conescharellina conica*, Haswell)* is a species of the Schizoporellidæ; *Cellepora tridenticulata*, Busk, found by the 'Challenger' expedition in the lamellar condition, is represented by several fossil specimens, some of them in the most regular *Lunulites*-form. Another *Cellepora* also occurs in this shape.

The genus *Cellepora* is, even when well-preserved recent specimens are available, a most difficult one to deal with, and with fossils where the terminal portion of the cell is often only imperfectly preserved the difficulty is immensely increased; but after repeatedly returning to this genus the results obtained are interesting. In a paper "On

* These two names were published in the same year, and I am unable to find out at present which has precedence.

the Use of the Opercula in the Determination of the Cheilostomatous Bryozoa"*, I figured the opercula of some *Celleporæ*, and pointed out that the "opercula may assist very much to bring this family out of its present confusion." Mr. Busk took up the idea, when working at the 'Challenger' Bryozoa, and the results he obtained are of great value; and I may say that my own collection of opercula indicates that many difficult genera may be brought into order by the study of the chitinous organs.

The opercula are, of course, wanting in fossils, but the exact knowledge of the oral aperture thus gained may nevertheless be used. In comparing recent with fossil species it is most important to study the opercula, and in describing this series of Australian collections such comparison has always been made when possible.

In the *Celleporæ* the shape of the zoœcial or vicarious (Busk) avicularia † is of great value; but I must here repeat what I have already said (Quart. Journ. Geol. Soc. vol. xxxix. p. 424) regarding other genera, namely, that the presence or absence of these avicularia cannot be made a specific character. Among several specimens of recent *Cellepora albirostris* from the Semaphore, Adelaide, there are some in which the vicarious avicularia abound; in one or two I do not find any; while in other cases, after searching over a large part of the colony in vain, a part is found where ten or twelve may come under the field of the microscope at the same time. Similar conditions obtain in recent *C. tridenticulata* from the same locality, and among the fossils we find the same thing; for in one large block of this species only one avicularium was found after a complete search among many thousand zoœcia. In the present paper the vicarious avicularia are figured of *Monoporella sexangularis*, corresponding with those already known from European localities, thus showing that it had been rightly determined before these avicularia were found. Many specimens of *Cellaria angustiloba* have now been examined; but it seems that avicularia have only been found in two cases. In the Australian fossil *Membranipora Michaudiana* only one has been found. In *Microporella elevata* most interesting lateral zoœcial avicularia are now for the first time made known. As bearing upon this subject, it may be mentioned that in reexamining my collection I was surprised to find in *Membranipora Dumerilii* a vicarious avicularium, so that here is a case of a common *Membranipora* in which none have previously been found now yielding an isolated example ‡.

Only a short time ago the presence or absence of these organs was

* Manchester Lit. & Phil. Soc. vol. xviii. p. 8, pl. i.

† These zoœcial avicularia have been named "onychocellaria" by Dr. Jullien; and it is doubtful whether it would not have been better to adopt this than to give a new name. The mandible he then names "onychocellium."

‡ Mr. Busk, in his paper "On the Use to be made of the Chitinous Organs" &c., describes a slender process rising from the middle of the base of the avicularian mandible, and this he terms the "columella," and here and in the 'Challenger' Report, p. xix., says that it only occurs in one division of the genus *Cellepora*, and in this division "only in those belonging to the southern hemisphere." This is by no means the case, as it is to be found in *Cellepora*

made a generic test, and the tendency still remains to attach great weight to their absence; but the instances furnished in this and former papers show that great caution is necessary here, though certainly when present they furnish characters of the greatest value. Their presence also often materially changes the general appearance of the colony, and no doubt many reductions of supposed species will have to be made, just as entomologists have frequently found that the male and female insects have received different names. We ought now to give greater attention to the nature of each character than to the general appearance of the zoarium, which often superficially varies greatly when young or old and from different depths.

Since my last paper was published the most valuable and interesting 'Report' on the 'Challenger' Bryozoa has appeared, in which, as we expected, Mr. Busk puts into our hands a series of splendid illustrations and concise descriptions. In this place we can only consider tnose parts which have a bearing upon the fossils found in Australia, and the number of representatives of this fossil fauna is not so large as we expected, but we find *Porina coronata*, Rss. (*Eschara gracilis*, Busk), *Schizoporella phymatopora* (*Myriozoum honolulense*, Busk), *Cellepora albirostris*, *C. tridenticulata*, and *Monoporella crassatina*, W., all of which seem to have been common fossils. It will be seen that the generic names used are not in every case the same; and we may point out that Mr. Busk has, of course, abandoned the classification which he found it convenient to adopt thirty-two years ago, before the labours of Smitt, Hincks, and others had shown that the zoœcial characters must be taken as of most importance. It is not, however, astonishing that Mr. Busk should now and then show a predilection for a style of classification not quite in accordance with the thorough changes which some of us feel must be adhered to; but these are now matters of detail, as the main modern principles are recognized, and we may say all leading authorities are now working in the same direction.

As instances, the divisions of the families Membraniporidæ and

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sardonica, W., from the Mediterranean, and in *C. coronopus*, *C. retusa*, var. *caminata*, and other species. Mr. Busk (*loc. cit.* p. 90, note) seems to have looked in vain in *C. sardonica* for it; but perhaps he only examined the oral avicularia, in which none are to be found, whereas in the small semicircular mandibles it is readily distinguished. On referring to a drawing of a mandible made when describing *C. sardonica* some years ago. I find that there is a large columella shown, and upon reexamination I find them usually quite distinct, though in some other species they are but rudimentary. In many species there is a denticle in this position rising from the calcareous bar which divides the avicularium, and this is shown in my figure of *C. sardonica* (Ann. & Mag. Nat. Hist. ser. 5, vol. iii. pl. 14. fig. 5), and may be seen in *C. albirostris*, *C. tridenticulata*, various *Reteporæ*, *Lepralia edax*, &c., being by no means confined to *Cellepora*. It is thus seen that it may sometimes be a useful character in determining fossils. The mandible of *Diachoris magellanica*, Busk, has a double "columella." I think that it will be found that what Mr. Busk describes as "short hairs" on the columella are only the remains of the attachment of muscular threads. The subject of the avicularian mandibles I have dealt with more fully in a paper which will appear in the Journal of the Royal Microscopical Society, ser. 2, vol. v. pt. iv.

Microporidæ seem singularly unfortunate, although, no doubt, *Membranipora* must be broken up, not merely because it has become unwieldy, but because species are included in it in which there are important differences of organization. It seems clearly advisable to include in one family only those forms in which the operculum is fixed in the flexible membrane covering the zoœcial area (opesia, Jullien), as in *Membranipora angulosa*, *M. membranacea*, &c.; whereas those like *Micropora uncifera*, Busk, which have a "complete" operculum placed in a corresponding aperture with a calcareous border should be placed in another family; but in the 'Report' *Amphiblestrum capense*, Busk *, a species in which the aperture is entirely closed by a thick operculum, is put among the Membraniporidæ, a family in which the calcareous aperture is opesial, and not opercular. Then again, under the Microporidæ, we find as type the genus *Micropora*, which always has an opercular opening; next, the genus *Vincularia*, in which there is an opesia, and in the membranous cover an operculum closely resembling those of *Membranipora angulosa*, Rss., *Selenaria maculata*, &c., while *Steganoporella* has opercular apertures.

Both *Vincularia* and *Eschara* are genera that have included widely divergent forms, and on the cylindrical, or erect bilaminar, mode of growth the genera have been based; therefore it is much to be regretted that they have been revived. Two species of *Eschara* are described. *E. elegantula*, Busk, as to the position of which we may at present withhold judgment; and *E. gracilis*, Busk, a species which is found in all stages, from a very delicate *Vincularia* form to large flat foliaceous growth, and which in this and former papers is called *Porina coronata*, Rss., a determination based upon direct comparison with typical *P. coronata* from the Italian Miocene, with recent specimens sent over by Mr. Haswell, and with a considerable series of Australian fossils. The divisions of the family Escharidæ are partly based upon the mode of growth, which is interesting for momentary classification, if we do not forget that the form is often so variable that we might almost call it accidental. This variability can be seen in *Cribrilina monoceros*, *C. terminata*, and over a hundred other species.

Myriozoum is a name given by Donati to the living erect cylindrical *M. truncatum*, which has some structures so different from those of the majority of the Chilostomata, that it is doubtful if it should not be placed in a separate division. The central spongy structure is entirely wanting in the species which Mr. Busk now places under *Myriozoum*, but probably all the 'Challenger' species will be found to fall into existing genera. *M. honolulense* is really in the Hemescharine stage, and is, in the present and previous papers, called *Schizoporella phymatopora*. *M. simplex* is known as *Cellepora margaritacea*, Pourtales, but cannot remain with the *Celleporæ*. The name of *M. immersum* must be changed, as it is very near to a species called *Onchopora immersa* by Mr. Haswell.

Mr. Busk proposes a genus *Adeonella* for forms which have pre-

* This I have from Algoa Bay.

viously been placed under *Microporella*, and as many occur fossil from Australia and other places, it becomes necessary to give especial attention to this new genus. It would certainly seem that a number thus placed have marked characteristics, which make it advisable to separate them; but Mr. Busk has certainly overlooked important points, which make it necessary to reduce his list very largely; for some have a median pore entering into the zoœcial cell, while others have a pore or opening above the opercular aperture, and every one, whatever his ideas of classification, will admit that this is a most important distinction, placing them in different families in spite of a certain similarity in general appearance. The importance of noticing the position of the median pore or opening I pointed out (Quart. Journ. Geol. Soc. vol. xxxviii. p. 269) when considering *Porina larvalis*, MacG., and this distinction is recognized by Mr. Busk when creating the genus *Haswellia*. My own collection is not very rich in these groups, but nevertheless is ample to study them. *Adeonella platalea*, Busk, for which I am indebted to Mr. Haswell, who sent it over as *Eschara hexagonalis*, is a most characteristic *Adeonella*, with oral operculum and avicularian mandible corresponding with Mr. Busk's figure, and here the pore enters into the peristome just above the operculum, which is placed very low down. *Adeonella polystomella*, Rss. (*Eschara Pallasii*, Heller), living near Naples and elsewhere in the Mediterranean, and fossil from the Miocene and Pliocene, has the characteristic operculum of the *Adeonella* group, and the central pore opens above the oral aperture, so that when a young cell is examined, there is no pore, but one is afterwards formed by the growth of the peristome which at an early stage bridges over the front, just as figured by Mr. Busk in *Smittia jacobensis* (pl. xix. fig. 7). The oral aperture of *Adeonella polystomella* has a sinus which is seen through the central pore. *Microporella violacea*, Johnst., which Mr. Busk would now include in a genus *Reptadeonella*, has a true median pore which enters into the zoœcial cavity, and is formed when the zoœcium is in an early stage. It also has an operculum with a straight edge, similar to that of *Microporella ciliata*, &c.

From Mr. Busk's figures and from specimens collected near Capri, it is clear that *Microporella distoma* is not an *Adeonella*, nor is *M. coscinopora*, Rss., which is distinct from *M. distoma*. *M. lichenoides*, M.-Edw., and *M. fissa*, Hincks, have also the median pores opening into the zoœcial cavity, and must at present be united with *Microporella*, though possibly they may some day be placed in a separate genus. This leaves us with *Adeonella polymorpha*, B.; *A. platalea*, B.; *A. intricaria*, B.; *A. atlantica*, B.; *A. pectinata*, B.; *A. polystomella*, Rss.

Seeing that the median pore of the Microporellidæ, and the central pore of *Adeonella* are structurally different, and that the oral aperture and operculum in the two families have different shapes, we feel sure that it merely requires this to be pointed out for Mr. Busk and every one else to see that they cannot be placed in the same genus; for it would be going back in classification if we were to be misled

by general appearance when the two most important characters are utterly different.

Mr. Busk frequently refers to the enlarged oœcial cells without giving figures, which is much to be regretted, as such cells are not always to be found, and in no species of *Adeonella* have I ever seen any. In *A. polystomella* the border cells are slightly larger and have but seldom an avicularium, and in many Cretaceous fossils with an Escharine growth the border cells are frequently larger than the central ones without there being reason to suppose that they are modified cells. The finding of a polypide (*loc. cit.* p. 178) in an ovicell is so entirely at variance with all our previous conceptions, that we should have been glad to have had fuller particulars and figures.

The collection here described furnishes 73 species, of which 46 are known living, bringing the number of Australian fossil Bryozoa described up to 220, of which just about half have been found living.

List of Species.

	Page.	Living.	Aldinga.	R.-Murray Cliffs.	Curdies Creek.	Mt. Gambier.	Bairnsdale.	Muddy Creek.	Allies and Localities.
1. Cellaria malvinensis, *Busk*	285	*	...	*	*	*	*	*	
2. —— angustiloba, *B.*	286	...	*	...	...	*	*	*	
3. Membranipora aperta, *Busk*	286	...	*	...	...	...	...	...	Crag.
4. —— circularis, *d'Orb.*	286	...	...	*	...	...	...	...	Cretaceous.
5. —— Savartii, *Aud.*	286	*							
6. —— radicifera, *Hincks*	287	*	...	*	*	*			
7. —— rhynchota, *Busk*	287	...	...	*	...	...	...	...	Crag.
8. —— temporaria, sp. nov.	288	...	...	*					
9. —— Flemingii, *Busk*	288	*	*						
10. —— cylindriformis, *Waters*	288	...	...	*	*	*	*		
11. —— parvicella, *T. Woods*	288	...	...	*	...	...	...	*	Bird Rock.
12. —— Michaudiana, *d'Orb.*	289	*	*						
13. —— trifolium, var.	289	*	*	*					
14. Micropora patula, *Waters*	290	...	*	*	*	*			
15. —— perforata, *MacG.*	290	*	*	...	...	*	...	...	Napier.
16. Monoporella crassatina, *Waters*	291	*	*	*	...	*	...	...	Napier; Waurn Ponds.
17. —— sexangularis, *Goldf.*	291	?	*	*	...	...	...	*	Orakei Bay.
18. Stenagoporella magnilabris, *B.*	292	*	...	*	*	*	*	*	
19. —— Rozieri, var. indica, *H.*	292	*	...	*	...	...	*		
20. Cribrilina radiata, *Moll.*	292	*	...	*	...	*			
21. —— figularis, *Johnst.*	293	*	...	*					
22. —— terminata, *Waters*	293	...	*	*	*	...	*	*	
23. Mucronella mucronata, *Sm.*	293	*	...	*	*	*	*	*	
24. —— nitida, *Verrill*	293	*	*	*	...	...	*		
25. —— coccinea, var. mamillata, *B.*	294	*	*	...	...	...	...	...	Crag.
26. —— coccinea, v. resupinata, *Manz.*	294	...	*	...	...	*			
27. Microporella grisea, *Lamx.*	294	*	...	...	...	...	...	*	
28. —— coscinopora, var. armata, *W.*	295	*	...	*	*	...	...	*	
29. —— violacea, *Johnst.*, var. fissa, *W.*	295	*	...	...	*	*	...	...	Adelaide.
30. —— symmetrica, *Waters*	295	...	...	*	*	...	...	*	Adelaide, Waurn Ponds.
31. —— ferrea, *Waters*	295	...	...	...	...	...	...	...	Adelaide.
32. —— pocilliformis, sp. nov.	295	...	*						
33. —— (Lunulites) magna, *Woods*	295	*	*	...	...	*			
34. —— magnirostris, *MacG.*	296	*	...	*	...	*			
35. —— elevata, *Woods*	296	...	*	*	*	*	*	*	
36. Porina coronata, *Rss.*	297	*	*	*	*	*	*	*	Adelaide, Bird Rock.
37. Lepralia edax, *Busk*	297	*	...	*	...	*	...	...	Crag.
38. —— depressa, var., *W.*	298	...	*	...	...	..	*		
39. —— rostrigera, *Sm.*	298	*	...	*					
40. —— escharella, *Römer*	298	...	*	...	...	...	...	...	Oligocene.
41. —— burlingtoniensis, *Waters*	299	...	*	*	...	*	*		

List of Species (continued).

	Page.	Living.	Aldinga.	R.-Murray Cliffs.	Curdies Creek.	Mt. Gambier.	Bairnsdale.	Muddy Creek.	Allies and Localities.
42. Lepralia subimmersa, *MacG.*	299	*	*						
43. —— confinita, sp. nov.	299	...	*						
44. Smittia Tatei, *T. Woods*	299	*	...	*	*	*	*	...	Waurn Ponds.
45. —— Landsborovii	300	*	...	*					
46. —— reticulata, *MacG.*	300	*	*						
47. —— seriata, *Rss.*	300	...	...	*	...	*			
48. —— Milneana, *B.*, v. coæquata, *W.*	300	...	*						
49. Schizoporella vulgaris, *Moll.*	300	*	*						
50. —— simplex, *J.*, var.	300	*	*						
51. —— phymatopora, *Rss.*	300	*	...	*	*	...	*		
52. —— striatula, *Sm.*	301	*	*	*					
53. —— fenestrata, *Waters*	301	...	...	*	*				
54. —— Cecilii, *Aud.*	301	*	...	*					
55. —— protensa, sp. nov.	301	...	*						
56. Mastigophora Dutertrei, *Aud.*	301	*	*	*					
57. Retepora marsupiata, *Sm.*	302	*	*	...	*	*	*		
58. Rhynchopora bispinosa, *Johnst.*	302	*	...	*					
59. Cellepora coronopus, *Busk.*	302	*	*	...	...	*			
60. —— avicularis, *Hincks*	303	*	...	*					
61. —— costata, *MacG.*	303	*	...	...	...	*	...	...	Adelaide.
62. —— divisa, sp. nov.	303	*	...	...	...	*	...	...	Crag ?
63. —— mamillata, *Busk*	304	*	...	*					
64. —— albirostris, *Sm.*	304	*	...	*					
65. —— pertusa, *Sm.*	305	*	*						
66. —— ——, var. ligulata, nov.	305	...	...	*					
67. —— biradiata, sp. nov.	306	...	...	*					
68. —— tridenticulata, *Busk*	306	*	*	*	...	...	...	...	Yorke's Peninsula.
69. —— fossa, *Haswell*	307	*	*	*	*	*			
70. —— ——, var. marsupiata, nov.	307	...	...	*					
71. Lekythopora hystrix, *MacG.*	308	*	...	*					
72. Cupularia canariensis, *Busk*	308	*	*	...	*				
73. Selenaria maculata, *Busk*	309	*	*	*	...	...	...	*	Bird Rock.

1. Cellaria malvinensis, Busk.

Salicornaria malvinensis, Busk, Cat. B.M. p. 18, pl. lxiii. figs. 1, 2; pl. lxv. (*bis*), fig. 1; 'Challenger' Rep. Zool. pt. xxx. p. 91, pl. xii. figs. 1, 5, 7.

Cellaria malvinensis, Waters, Quart. Journ. Geol. Soc. vol. xxxvii. p. 321, pl. xiv. fig. 3.

Salicornaria immersa, T. Woods, Corals and Bry. of Neoz. Per. in New Zealand Colon. Mus. & Geol. Surv. 1880, p. 27, fig. 27.

There are a few small fragments of *Cellaria* from the River-Murray Cliffs, and in only one piece is there a zoœcial avicularium. This avicularian cell is of the same shape as a zoœcium, but is slightly smaller, with a wide avicularian aperture. Possibly a second species is also represented. *C. malvinensis* was found by the 'Challenger' widely distributed in the southern hemisphere in depths varying from 5 to 1450 fathoms.

Loc. Living: Falkland Island, South Patagonia, Straits of Magellan (*Darwin*). Six stations of 'Challenger' Exped., from Kerguelen, Marion Island, S. America, Fiji Islands. New Zealand (*Hutton*). Port Wellington (*Miss Jelly's Coll.*). Fossil: Mt. Gambier, Bairnsdale, Muddy Creek, Curdies Creek (Australia).

Nelson (from Leda marls vi.), Waipukerau, Shakespeare Cliff (Wanganui) [New Zealand].

2. Cellaria angustiloba, Busk; Waters, Quart. Journ. Geol. Soc. vol. xxxviii. p. 260, pl. ix. figs. 28–30.

The avicularia are all situated at the edge of the zoarium. The notch noticed in the avicularium of the Mount-Gambier specimens is not distinguishable in the Aldinga fossil.

3. Membranipora aperta, Busk. (Pl. VII. fig. 3.)

Membranipora aperta, Busk, Crag Polyzoa, p. 33, pl. iii. fig. 13.

A specimen from Aldinga has the zoarium conical, resembling *Lunulites*. The opesial opening is about 0·4 millim. long and 0·25 millim. broad, and the avicularia are about the same size. The avicularium has three openings, the upper one large, triangular; below this a slit-like opening, and still lower down a semilunate opening; when these last two are broken down, they form a single opening, as figured by Busk. There is one distal rosette plate which is semilunate.

This is not the *Membranipora aperta* of Manzoni (Bri. di Castrocaro, p. 9, pl. i. fig. 4).

Loc. Coralline Crag.

4. Membranipora circularis, d'Orb.

Flustrina circularis, d'Orb. Pal. Franç. p. 305, pl. 602. figs. 11–13.

? *Membranipora tuberculata*, Busk, Crag Polyzoa, p. 30, pl. ii. fig. 1.

In a specimen from the River-Murray Cliffs the zoarium consists of many layers, forming an irregular subglobular mass, but perhaps the colony commenced on a *Cellepora*. The opesia are variable, in some cases being quite round, in others subtriangular, with the lower edge straight and rounded, and contracted towards the top; in other cases the opening is more oval. Opesia of average cell 0·20–0·25 millim. long. There are two small avicularia above each opesial opening; but as the zoœcia are arranged in quincunx, this makes them appear as if surrounded by six avicularia.

The structure of *Flustrina baculina*, d'Orb., and *F. pentagona* is similar.

Loc. Sougé, près de Vendôme (Loir et Cher), Cretaceous; River-Murray Cliffs.

5. Membranipora Savartii, Aud.

Membranipora ligerensis, d'Orb. loc. cit. p. 550, pl. 607. figs. 5, 6.

Flustrellaria tubulosa, d'Orb. loc. cit. p. 532, pl. 727. figs. 9, 10.

Membranipora subtilimargo, Reuss, Bry. Œst. Ung. Mioc. p. 179 (39), pl. ix. fig. 3.

Membranipora Lacroixii, Reuss, loc. cit. p. 40, pl. ix. fig. 8.

? *Membranipora reticulum*, Reuss, Foss. Polyp. d. Wien. Tert. p. 98, pl. xi. fig. 25.

Vaginopora texturata, Reuss, loc. cit. p. 73, pl. ix. fig. 1.

Membranipora Savartii, Busk, Crag Polyzoa, p. 31, tav. ii. fig. 6.

Biflustra Savartii, Manzoni, Bri. di Castrocaro, p. 38, pl. ii. figs. 17, 17*a*; Smitt. Floridan Bry. p. 20, tav. iv. figs. 92–95; Busk, Rep. of 'Challenger' Polyzoa, p. 67, pl. xiv. fig. 2.

Biflustra delicatula, Busk, Crag Polyzoa, p. 72, pl. i. figs. 2 & 4, pl. ii. fig. 7; Manzoni, Bry. foss. Ital. Contr. II. p. 4, pl. i. fig. 5; MacGillivray, Zool. of Vict. decade vi. p. 28, pl. 57. fig. 2.

For further synonymy, see Smitt's 'Floridan Bryozoa,' to which list probably several fossil *Membraniporæ* should be added.

I have some rather large pieces of bilaminate *Biflustra delicatula* from the Crag of Leiston, in which I am unable to find any denticle within the lower margin, and Professor MacGillivray draws attention to the fact that it exists only in two or three of the cells of the Queenscliff specimen, and is altogether absent in those from Queensland. In the Italian Pliocene fossil species I do not find it, nor does it seem to occur in the Australian or New Zealand fossils that I have examined; on the other hand, in a recent specimen, in the Vincularia-form, from Palm Island, it is seen in all the zoœcia. Smitt has called attention to the inconstancy of the tubercles in this species; and in a recent specimen from Penang, some zoœcia have tubercles while others are without. The recent specimen from Penang has the opesia about 0·3 millim. long and 0·24 millim. wide, which is slightly smaller than in the fossil adnate upon a *Retepora* either from Aldinga, or the River-Murray Cliff. *Biflustra regularis*, d'Orb., from Royan, is very closely allied, with rather larger opesial openings.

Loc. Senonian of France, Miocene of Austria. Crag and Pliocene of England, Italy, and Sicily. Living: Florida, 29 fathoms; Queenscliff (Victoria); Port Curtis (Queensland); Philippine Islands, 10 fathoms; Penang, &c.

6. MEMBRANIPORA RADICIFERA, Hincks; Waters, Quart. Journ. Geol. Soc. vol. xxxviii. p. 262.

In a specimen from the River-Murray Cliffs there are small open spaces between the zoœcia.

7. MEMBRANIPORA RHYNCHOTA, Busk. (Pl. VII. fig. 1.)

Membranipora rhynchota, Busk, Crag Polyzoa, p. 33, pl. iii. fig. 7.

A specimen from Aldinga is in the Eschara-form. The zoœcia have large opesial openings 0·3 millim. long and 0·2 millim. wide. Below the opesia there is a large avicularium, with its opening much prolonged, and with the end very narrow for the acute mandible. The ovicell, with a keel down the centre and slightly depressed at each side, is surmounted by an avicularium.

There has been much confusion with this species, as by an oversight Mr. Busk gave a description of *M. minax* as *M. rhynchota*

(Q. J. Mic. Soc. viii. p. 125), and the fossil from Bruccoli, which I called *Biflustra rhynchota*, should be renamed.

Loc. Crag.

8. MEMBRANIPORA TEMPORARIA, sp. nov. (Pl. VII. fig. 16.)

Although this *Membranipora* comes very near to several species, I have been unable to identify it with any. The zoœcia are very large, with a large opesia, about 0·6 millim. long, whereas in few species is it more than 0·3–0·4 millim. Above each zoœcium there are two avicularia with oval openings directed outwards. The ovicell is small, short, and but little raised. The species in most particulars corresponds with *M. pura*, Hincks, but that has spines in place of the avicularia.

Loc. River-Murray Cliffs.

9. MEMBRANIPORA (AMPHIBLESTRUM) FLEMINGII, Busk.

Membranipora Flemingii, Busk, Cat. B. M. ii. p. 58, pl. lxxxiv. figs. 3–5 (only); Hincks, Brit. Mar. Polyzoa, p. 162, pl. xxi. fig. 1–3.

A specimen from Aldinga is growing upon a *Retepora*. There has been considerable confusion with the species, as it was at first made to include forms which have since been separated, but the fossil is undoubtedly *Membranipora Flemingii*, as defined by Mr. Hincks. It has the six oral spines, an ovicell similar to recent specimens, and sometimes two avicularia below the area, but more frequently there is only one, and this often at the end of a long tubular projection. In some cases this chimney-like avicularium is nearly as long as a zoœcium. In no recent specimen has the avicularium been found as much elevated, though it is always raised.

MacGillivray refers (Trans. Roy. Soc. Vict. vol. xviii. p. 120) with doubt to specimens "seemingly referable to" *M. Flemingii*, from Port Phillip Heads, Victoria.

Loc. Recent; European Seas, widely distributed.

10. MEMBRANIPORA (AMPHIBLESTRUM) CYLINDRIFORMIS, Waters, Quart. Journ. Geol. Soc. vol. xxxvii. p. 323, pl. xvii. fig. 74, and vol. xxxviii. p. 263, pl. viii. fig. 13.

11. MEMBRANIPORA (AMPHIBLESTRUM) PARVICELLA, T.-Woods. (Pl. VII. fig. 5.)

Selenaria parvicella, T.-Woods, Trans. Phil. Soc. Adelaide, 1880, p. 10, pl. ii. fig. 10; Waters, Quart. Journ. Geol. Soc. vol. xxxix. p. 441.

Some fragments from the River-Murray Cliffs are better preserved than those from Muddy Creek and Bird Rock; and here we see there was a spine, or process, over the elongate "avicular (?) cells," and a broad denticle within the lower margin of the zoœcial cells. The dorsal surface is granulated, with a few large pores, and is divided by parallel lines, which apparently radiate from the centre of the colony; cross-lines, which are very indistinct, divide the dorsal surface into zoœcial areas. The lateral rosette-plates form a regular

line along the middle of the lateral walls, and correspond with those of *Biflustra delicatula*, Busk, with which perhaps this species should be united.

Mr. Woods's description and figures are from the fossil upside down.

12. MEMBRANIPORA (AMPHIBLESTRUM) MICHAUDIANA, d'Orb.

Cellepora Michaudiana, d'Orb. Pal. Franç. p. 404, pl. 604. figs. 7, 8, pl. 712. figs. 3, 4.

Membranipora permunita, Hincks, Ann. & Mag. Nat. Hist. ser. 5, vol. vii. p. 151, pl. x. fig. 2; MacGillivray, Trans. Roy. Soc. Vict. vol. xviii. p. 118.

Membranipora falcata, MacGillivray, Trans. Roy. Soc. Vict. vol. ix. p. 132.

The fossil differs from a recent specimen dredged off the coast of Victoria in having the zoœcia and also the opesia a trifle smaller. The avicularium of this fossil and of the one figured by d'Orbigny is a little smaller than that in the recent specimens, in which it occurs at the base of an abortive zoœcium; at least, this is my interpretation of a very curious structure, but this does not seem to be Mr. Hincks's view, and it is well worth further examination. In the fossils the ovicells are simply rounded, without a raised rib; and this is the case in some of the ovicells of my recent specimens, while others have it.

Perhaps the recent forms should rank as *M. Michaudiana*, var. *permunita*, on account of the small zoœcia to which the avicularia are attached.

Loc. Fossil: Cretaceous; Le Mans, Le Hâvre, Tourtenay; Aldinga (growing on *Microporella elevata*). Living: off Curtis Island, Bass's Straits; off Victoria (on *Adeona*), Schnapper Point (*MacG.*).

13. MEMBRANIPORA (AMPHIBLESTRUM) TRIFOLIUM, Busk, var. PROPINQUA.

Lepralia trifolium, MacG. Trans. Roy. Soc. Vict. 1868, p. 9; Prod. of Zool. of Vict. decade iv. p. 28, pl. xxxvii. fig. 2.

The fossil from Aldinga has the zoœcial avicularia and globular ovicells described by MacGillivray. The aperture (opesia) is about the same size as that of a Crag specimen of *Membranipora trifolium*, Busk, in my possession, but it differs in having a zoœcial avicularium (onychocellarium) and no other avicularia. The zoœcia, in shape, are very similar to those of recent *Selenaria maculata*, Busk. In the Report on the 'Challenger' Polyzoa, Mr. Busk figures as *Amphiblestrum umbonatum* (pl. xv. fig. 66) a species or variety with avicularia, which is closely allied to this.

It is strange that two forms so closely allied as *Membranipora trifolium*, Busk, and *Lepralia trifolium*, MacGillivray, should have received the same specific name when placed under different genera.

The genus *Amphiblestrum* may be a convenience, but, as at present defined, it cannot be looked upon as sharply separated, and

with a large number of species it would be extremely difficult to say whether they should be placed in *Membranipora* or *Amphiblestrum*. We see in *A. papillatum*, Busk, that it really has a thick border extending inwards, and not a plate, as in *Membranipora Rosselii*. As the genus *Membranipora* is so large, and contains such a variety of forms, it is to be hoped that other characters may be found to separate this genus more definitely.

Loc. Living: Queenscliff, Williamstown, and Western Port (*MacG.*). Fossil: Aldinga and River-Murray Cliffs,

14. Micropora (?) patula, Waters. (Pl. VII. fig. 4.)

Micropora patula, Waters, Quart. Journ. Geol. Soc. vol. xxxvii. p. 326.

Steganoporella patula, Waters, Quart. Journ. Geol. Soc. vol. xxxviii. p. 265, pl. ix. fig. 31.

A specimen from the River-Murray Cliffs, in the Lepralia-stage, is much better preserved than the one from Curdies Creek or Mt. Gambier, and has below many zoœcia a zoœcial (?) avicularium, surrounded by an almost circular border, within which is the mandibular area, also surrounded by a granulated border, which is at the lower end narrow, but at the distal end becomes very broad. The avicularian opening is small and slit-like. Above the oral aperture there is a small ovicellular opening. The ovicell is scarcely at all raised, and would certainly be overlooked if it were not for this small opening; but in some cases the front wall is broken away, and then the ovicell-chamber is distinctly seen. At each side of the ovicellular aperture there is a depression or opening.

A similar supraoral opening has been figured in *Membranipora semiaperta*, Reuss, *Escharinella muralis*, Gabb & Horn, *Reptoflustrina heteropora*, G. & H., and *Cellepora Mohli*, Hagenow.

Loc. Curdies Creek, Mt. Gambier, River-Murray Cliffs.

15. Micropora perforata, MacG.

Membranipora perforata, MacGillivray, Trans. Phil. Instit. Vict. 1859; Nat. Hist. of Vict. decade iii. p. 29, pl. xxv. fig. 2.

When speaking of var. *clausa*, Waters (Quart. Journ. Geol. Soc. vol. xxxviii. p. 505), I pointed out that *Monoporella lepida*, Hincks, was allied to *M. perforata*, MacG., but they must be separated, either as varieties or species, on account of the much more fully developed avicularium of *M. lepida*, though the position and direction of the avicularium is similar. From Napier, New Zealand, there are specimens of *M. perforata* without avicularia, and others in which the small avicularium described by MacGillivray is pretty constant. In many zoœcia in these Napier fossils there are several pores, as in recent *M. lepida*, from New Zealand; whereas in the Aldinga fossils it is rare to find more than the two below the aperture. The zoœcia of the Australian fossils are very regular; but those from Napier show great variation in this respect, and therefore it is very probable that *Steganoporella elongata*, Hincks, is only a synonym.

Aperture about 0·1 millim. wide, which is slightly smaller than that of *M. lepida*.

Loc. Living: Queenscliff &c., Australia. Fossil: Aldinga, Mt. Gambier (Australia); Napier, and Tanners Run (New Zealand).

16. MONOPORELLA CRASSATINA, Waters.

Monoporella crassatina, Waters, Quart. Journ. Geol. Soc. vol. xxxviii. p. 270, pl. vii. fig. 8; ibid. vol. xxxix. p. 435.

Lepralia japonica, Busk, 'Challenger' Report on the Polyzoa, Cheil. p. 143, pl. xvii. fig. 5.

Loc. Living: Cobie, Japan 8–10 fathoms (Busk). New Zealand (from Miss Jelly). Fossil: Napier and Waipukerau (New Zealand); Mt. Gambier, Waurn Ponds, Aldinga, River-Murray Cliffs (Australia).

17. MONOPORELLA SEXANGULARIS, Goldf. (Pl. VII. fig. 2.)

Eschara sexangularis, Goldf.; Hagenow. Maast. Kreide, p. 81, pl. x. figs. 3, 4, 5.

Eschara Clarkei, T.-Woods, Trans. Roy. Soc. N. S. Wales, 1876, p. 2, figs. iv.–vii.

? *Eschara piriformis*, Sturt, 'Two Exped. Interior S. Austr.' 1833, ii. p. 253, pl. 3. fig. 2.

Vincularia maorica, Stoliczka, Bry. Orak. p. 153, pl. xx. fig. 8.

Monoporella sexangularis, Waters, Quart. Journ. Geol. Soc. vol. xxxix. p. 435.

Biflustra excavata, Manzoni, Bri. foss. del Mioc. d'Aust. ed Ung. p. 67 (19), pl. xiii. fig. 14.

There are two specimens from Aldinga, both fenestrate. In the one the fenestræ are about 4 millim. long, in the other they are 7–8 millim., and in the first there are zoœcial avicularia (onychocellaria), of the same shape as those figured by Hagenow, but without the great elongation. The avicularian opening is elongate in the centre of the avicularium. In my former paper I pointed out that, although identifying it with Hagenow's species, I had not found any avicularia in either; and it is interesting to find that this character now justifies the determination. The oral aperture (0·22 millim.) is rather smaller than in the specimens from Muddy Creek &c.; and in the zoœcia surrounding the fenestræ, there is not any oral opening, but an elongate slit, much like the avicularian opening. Beissel describes and figures such border cells in his *Eschara pulchra*, and blind cells are found in *Adeona* and other Chilostomata. There is also a non-reticulated specimen from the River-Murray Cliffs, which Prof. Tate marked *Eschara piriformis*, Sturt; but the *E. piriformis*, Goldf., of the Maestricht beds has much larger zoœcia, with very large opesial opening (0·6 millim.) nearly as wide as the zoœcium.

Some are flat bilaminate expansions, one is flattened and foliaceous, while others are subcylindrical, and this Vincularia-form no doubt represents the *Vincularia maorica* of Stoliczka; and now that I have seen these, I consider that the fossil from Curdies Creek might be called var. *minima* or var. *tuberculata*.

Loc. Orakei Bay, New Zealand (in Vincularia-form); Muddy Creek, Bird Rock, Waurn Ponds, Murray Cliffs, Aldinga (reticulated and also a compressed branch).

18. STEGANOPORELLA MAGNILABRIS, Busk; Waters, Quart. Journ. Geol. Soc. vol. xxxviii. p. 506.

From the River-Murray Cliffs there are specimens in the Escharan and Hemescharan forms.

In *S. magnilabris* the cells where division is about to take place are larger than the others, so that the large characteristic cells of *Steganoporella* are found to be followed by two smaller ones, each of which commences a new row. The same thing is seen in *Biflustra delicatula* from the Crag, and in other species.

With a cylindrical mode of growth, as in *S. neozelanica,* there is no frequent multiplication of the rows, and no large cells are found.

Mr. Busk, however ('Challenger' Report, p. 76), points out that the operculum of *S. neozelanica* differs from that of *S. magnilabris,* which is the case, as the former has numerous irregular bars across the operculum, and four large teeth instead of the numerous small ones; and therefore I agree with him that they must be separated.

Loc. Living: see *loc. cit.* p. 506, and Honoruru, Sandwich Islands (20–40 fathm.) (Busk). Fossil: Miocene; Castelgomberto? Mouille Mougnon (Cant. Vaud); Curdies Creek, Mt. Gambier, Bairnsdale, Batesford, River-Murray Cliffs (Australia); Waipukerau and Petani (New Zealand).

19. STEGANOPORELLA ROZIERI, Aud., var. INDICA, Hincks.

Steganoporella Rozieri, Hincks, Ann. & Mag. Nat. Hist. ser. 5, vol. vi. 1880, p. 379, pl. xvi. figs. 1, 1 *a*.

For other synonyms see Waters, Quart. Journ. Geol. Soc. vol. xxxviii. p. 505.

In the specimens from the River-Murray Cliffs, the zoarium is in the Vincularia-form, with about eight series of zoœcia round the axis. There is a large opening replacing a zoœcium, which is apparently the aperture of a large elongate avicularium; but from the state of preservation I do not feel sure about this interpretation, and possibly we have here only a broken-down zoœcium. There are no other avicularia.

Loc. Living: India, Marion Islands, Holborn Islands, Darnley Islands, Torres Straits. Miocene: Söllingen. Bairnsdale, River-Murray Cliffs.

20. CRIBRILINA RADIATA, Moll. (*non* d'Orb.).

For synonyms see Hincks, Brit. Mar. Polyzoa, p. 185, and Waters, Quart. Journ. Geol. Soc. vol. xxxviii. p. 265.

The specimen from the River-Murray Cliffs has eight ridges on each side, a suboral pore, avicularia with a wide base but elongate, scattered among the zoœcia, ovicell globose, about two thirds as wide as the zoœcia; oral aperture 0·09 mm. wide.

Loc. Living: European seas, Madeira, Florida, Bass's Straits. Fossil: European Eocene, Miocene, Pliocene, and Postpliocene, and Mt. Gambier.

21. CRIBRILINA FIGULARIS, Johnst.

Lepralia figularis, Johnston, Brit. Zooph. ed. 2, p. 314, pl. lvi. fig. 2.

Cribrilina figularis, Hincks, Brit. Mar. Polyzoa, p. 196, pl. xxvi. figs. 5–7.

Cribrilina philomela, Busk, var. *adnata*, Busk, 'Challenger' Re port on the Polyzoa, pt. xxx. p. 132, pl. xxii. fig. 7.

A specimen from the River-Murray Cliffs has characteristic zoœcial avicularia (onychocellaria), which correspond most nearly with those figured for *C. figularis*, var. *fissa*, Hincks (*loc. cit.* fig. 8). This, like var. *adnata*, has numerous costæ (nine on each side); more of the front is covered with costæ than in Mr. Hincks's figures, but not quite as much as in Mr. Busk's. Oral aperture 0·13 mm., which is about the same as in the Australian species.

Loc. Living: British, French, and Mediterranean seas; Capri, 40 fathoms; off Marion Islands, 50–75 fath.; Heard Islands, 75 fath. Fossil: River-Murray Cliffs, Crag (*Bell*).

22. CRIBRILINA TERMINATA, Waters.

Cribrilina terminata, Waters, Quart. Journ. Geol. Soc. vol. xxxvii. p. 326, pl. xvii. fig. 68, vol. xxxviii. p. 507, pl. xxii. fig. 6, and vol. xxxix. p. 436, pl. xii. fig. 17.

A specimen from the River-Murray Cliffs has two or three minute avicularia above the oral aperture, and the zoœcial avicularia are narrower than the one figured from Muddy Creek (*l. c.* vol. xxxix. pl. xii. fig. 17).

Loc. Fossil: S.W. Victoria, Bairnsdale, Muddy Creek, and the River-Murray Cliffs.

23. MUCRONELLA MUCRONATA, Smitt; Waters, Quart. Journ. Geol. Soc. vol. xxxvii. p. 328, pl. xvii. fig. 66, vol. xxxviii. pp. 266 & 507, and vol. xxxix. p. 436.

The mucro supports an avicularium directed forwards. It occurs in Eschara- and Hemeschara-form.

24. MUCRONELLA NITIDA, Verrill.

Discopora nitida, Verrill, Amer. Journ. Science, vol. ix. p. 415, pl. vii. fig. 3 (1875).

Mucronella nitida, Verrill, Proc. U. S. Nat. Mus. p. 195; Waters, Quart. Journ. Geol. Soc. vol. xxxviii. p. 507.

Smittia nitida, Hincks, Ann. & Mag. Nat. Hist. s. 5, vol. vii. p. 159, pl. ix. figs. 5, 5 *a*.

Lepralia reticulata, var. *inæqualis*, Waters, Ann. & Mag. Nat. Hist. ser. 5, vol. iii. p. 41, pl. ix. fig. 3.

Smittia trispinosa, Johnst., var. *ligulata*, Ridley, Proc. Zool. Soc. London, 1881, p. 53, pl. vi. fig. 9.

The Murray-Cliff fossil incrusts a *Cellepora*. It shows considerable variation in the size of the avicularia; sometimes they are ligu-

late; on other zoœcia they expand considerably towards the extremity. With a form like the present it is difficult to know whether it should be called *Smittia* or *Mucronella*, and the two genera are not sharply defined.

Mucronella delicatula, Busk, Chall. Rep. p. 156, is, no doubt, closely related; but the triangular mandible shows that the two forms are not absolutely identical. I have a specimen dredged from the coast of Victoria which has a narrow ligulate avicularium, but I do not think that it ought to be separated from those with a larger avicularium, as the shape is approximately the same. Mr. Busk calls attention to the central denticle being in front of the operculum, as if it were exceptional; but this is the rule in this family.

Loc. Living: Vineyard Sound and Long Island Sound (*V.*); Africa (*H.*); Victoria Bank, S.E. Brazil (32 fath.); Victoria (on *Adeona*); Naples (*W.*). Fossil: Crag (*W.*), Bairnsdale and River-Murray Cliffs. This or a variety fossil from Waipukerau and Napier (New Zealand).

25. Mucronella coccinea, Abildgard, var. mamillata, Busk.

A specimen from Aldinga incrusted a *Cerithium* or allied shell. The surface is smooth or faintly sulcate, with a single or double row of pores round the base. The ovicell is very small and decumbent. The fossil is so badly preserved that it was not readily recognized.

Loc. Living: coast of Antrim. Fossil: Crag, Aldinga.

26. Mucronella coccinea, Abildgard, var. resupinata, Manz.

Mucronella coccinea, Waters, Quart. Journ. Geol. Soc. vol. xxxviii. p. 266.

In well-preserved avicularia it is clear that the mandible was spatulate, but the avicularian opening triangular.

Loc. Aldinga; Mt. Gambier.

27. Microporella grisea, Lamx., form Adeona.

Adeona grisea, Lamouroux, Expos. Méth. p. 40, pl. lxx. fig. 5; Kirchenpauer, "Ueber die Bry. Gatt. *Adeona*," Journ. Mus. Godeffroy, 1879, p. 9, pl. i. fig. 8, 8*a*.

Dictyopora grisea, MacGillivray, Nat. Hist. of Vict. decade vii. p. 23, pl. 66. fig. 1, 1*a*, *b*, *c*, *d*.

Dictyopora cellulosa, MacGillivray, Trans. Roy. Soc. Vict. 1868; Nat. Hist. Vict. decade v. p. 37, pl. xlvii. fig. 1, and decade vii. pl. lxvi. fig. 1*e*.

Adeona cellulosa, Kirchenpauer, *op. cit.* p. 10.

Microporella cellulosa, form *Adeona*, Waters, Quart. Journ. Geol. Soc. vol. xxxix. p. 437.

From Muddy Creek there is a fragment spreading out in flabelliform manner from the base, to which probably a flexible stem was attached.

From the range of zoœcial variability found in specimens that I have examined, and from the published descriptions, there does not seem to be sufficient reason for separating *M. grisea* from *M. cellulosa*.

Loc. Living: various Australian localities. Fossil: Muddy Creek.

28. MICROPORELLA COSCINOPORA, Reuss, var. MUCRONATA, MacG.

Lepralia mucronata, MacGillivray, Tr. Roy. Soc. Vict. 1868.

Eschara mucronata, MacG., Nat. Hist. Vict. dec. v. p. 43, pl. xlviii. figs. 6, 7.

Microporella coscinopora, Reuss, var. *armata*, Waters, Quart. Journ. Geol. Soc. vol. xxxvii. p. 331, pl. xv. fig. 25.

Loc. Living: Queenscliff and Schnapper Point (MacG.), Port-Philip Heads (A. W. W.). Fossil: Curdies Creek, Muddy Creek, River-Murray Cliffs.

29. MICROPORELLA VIOLACEA, Johnst., var. FISSA, H.

Microporella fissa, Hincks, Ann. & Mag. Nat. Hist. ser. 5, vol. vi. p. 381, pl. xvii. fig. 4.

30. MICROPORELLA SYMMETRICA, Waters, Quart. Journ. Geol. Soc. vol. xxxvii. p. 332, pl. xviii. fig. 83.

31. MICROPORELLA FERREA, Waters, *loc. cit.* p. 330, pl. xvii. fig. 72.

32. MICROPORELLA POCILLIFORMIS, sp. nov. (Pl. VII. fig. 8.)

Zoarium dome-shaped, 7 mm. diameter, in growth resembling *Cupularia*. Zoœcia suboval, convex, surface covered with large pores, with a raised suboral pore just below the oral aperture. Oral aperture rounded at the distal end, straight below, 0·24 mm. broad. There are two distal rosette-plates, each of which usually has two openings. On the under surface of the colony the area of each zoœcium is distinctly marked and is convex.

Loc. River-Murray Cliffs.

33. MICROPORELLA MAGNA, T.-Woods. (Pl. VII. fig. 7.)

Lunulites magna, T.-Woods, Trans. Phil. Soc. Adelaide, 1880, p. 7, pl. i. fig. 6*a*–6*d*.

Zoarium large (25 mm. diam.), dome-shaped, consisting, in the specimen examined, of one layer of zoœcia, slightly elevated along eight lines radiating from the centre; Mr. Woods says, "In the younger specimens . . . . irregularly pentagonal; in the older specimens . . . . irregularly lobed or sinuated."

On each side of these lines the direction of the avicularia is opposed, being directed diagonally upwards to the right on one side and diagonally upwards to the left on the other side.

Zoœcia raised, especially near the aperture, with large pores over the surface and a large suboral pore below the aperture. Oral aperture large (0·23 mm. wide), straight on the proximal edge with the corners rounded; the distal edge of the aperture forms half a circle. The true shape of the aperture is sometimes obscured in the older cells. Avicularia large, broad; aperture pointed above, rounded below. I have not had the opportunity of examining the

under surface of the zoarium; but Mr. Woods says, "Under surface finely radiately ridged, with a narrow slit-like pore at the margin."

Loc. Mr. T.-Woods gives Aldinga and Mt. Gambier.

34. MICROPORELLA (DIPORULA) MAGNIROSTRIS, MacG.

Microporella introversa, Waters, Quart. Journ. Geol. Soc. vol. xxxviii. p. 268, pl. ix. figs. 33, 34.

Lepralia magnirostris, MacGillivray, "New or Little-known Polyzoa," pt. 2, Trans. Roy. Soc. of Victoria, vol. xix. p. 134, fig. 6.

Specimens from the River-Murray Cliffs grow either in the Hemescharan form when the dorsal surface is coarsely granulated and has large pores, or in superposed layers with zoœcia of the same size as those from Mt. Gambier, but in a better state of preservation; and here the central pore is very distinct and raised, but with a cleft in the upper (distal) part of the raised tube surrounding the pore. This better-preserved material shows that I was misled in supposing that the avicularia were directed inwards; I then attributed the avicularia to the wrong zoœcia.

Loc. Fossil: Mt. Gambier; River-Murray Cliffs. Living: Port-Philip Heads.

[Since this paper was read, Miss Jelly has sent me a recent specimen from Port-Philip Heads (Australia). This is in the Hemeschara-form, but the dorsal surface was perhaps attached to a sponge, as it is studded with large erect pore-tubes resembling those on the dorsal surface of *Selenaria maculata*, and besides these there are calcareous offsets, which are traversed by numerous tubes, and appear to have a sponge-like structure. I hope to make a further examination and sections of these interesting radicles.]

This and the last species are very closely allied and should perhaps be united under one name. In both the recent specimen and the one from the River-Murray Cliffs the peristome is more raised than in the one I figured.

35. MICROPORELLA ELEVATA, T.-Woods. (Pl. VII. figs. 6 and 9.)

Eschara elevata, T.-Woods, Trans. R. Soc. N.S.W. 1876, p. 2, fig. 10.

Microporella elevata, Waters, Quart. Journ. Geol. Soc. vol. xxxvii. p. 330, pl. xvii. figs. 63, 64, pl. xviii. fig. 90.

When describing the fossil from Curdies Creek I pointed out the great difference in zoœcia from different parts of the same colony, and some well-preserved specimens from the River-Murray Cliffs, showing in places the structure given in fig. 63 (*loc. cit.*), have in other parts a much more regular and elaborate structure. The peristomial region is raised and surrounded by a ridge, with small pores within the area thus formed; down the middle of each zoœcium there is a straight ridge which expands at the lower part of the zoœcium, surrounding the median pore. On each side of this line there are large irregular openings.

There are very curious zoœcial avicularia occurring only near the border of the colony with a nearly round aperture divided by a cross bar near the lower edge.

Loc. Curdies Creek; Mt. Gambier; Bairnsdale; Muddy Creek; Spring Creek; River-Murray Cliffs.

36. Porina coronata, Reuss.

For synonyms, see Waters, Quart. Journ. Geol. Soc. vol. xxxviii. p. 333, to which add:—

Eschara gracilis, MacGillivray, Nat. Hist. of Vict. decade v. p. 40, pl. xlviii. fig. 3; Busk, 'Challenger' Report, Zool. pt. xxx. p. 141, pl. xxi. fig. 6.

Porina gracilis, Hincks, Ann. & Mag. Nat. Hist. 1881, p. 60, pl. iii. fig. 5.

Haswellia australiensis, Busk, *loc. cit.* p. 172, pl. xxiv. fig. 9.

Before describing *Porina coronata* from Curdies Creek (Quart. Journn. Geol. Soc. vol. xxxvii. p. 333. I had received from Mr. Haswell specimens of his *Myriozoum* (*Haswellia*) *australiense*, in which the peristome is tubular, often entirely surrounded by openings which are either simple pores or have avicularian covers. There is great irregularity in these peristomial pores or avicularia, so that very frequently there is only an avicularium below the aperture; in other parts in the same colony there may be two or three at the side; in others they regularly surround the aperture. Sometimes the peristome is flattened on the distal edge. The central pore (median pore) is usually only a rounded aperture; at other times in the same colony from Holborn Island (collected by Mr. Haswell) it has a tubular projection; to show an extreme case, I figured from Curdies Creek a very delicate specimen with very marked tubular pores; and upon reexamination, I find that from such a specimen to the large flat growth there is no break in the series, so that I feel quite convinced that the determinations then made were correct.

The opercula of the specimen sent as *M. australiense* are slightly smaller than those from typical *E. gracilis*, but the shape is the same, and so is the attachment of the muscles. As the ridge for the muscular attachment is characteristic, and differs from any other with which I am acquainted, this species may be made a test case, showing that the modern classification is an advance upon that which laid the greatest stress on the mode of growth. In both fossil and recent specimens the pore is sometimes elongate, sometimes round.

The fossils from the River-Murray Cliffs, Aldinga, and Adelaide are all either in the form *b*, as *vertebralis* (see Bry. from S.W. Victoria, p. 334), or are a little flattened.

37. Lepralia edax, Busk.

Cellepora edax, Busk, Crag Polyzoa, p. 59, pl. ix. fig. 6, pl. xxii. fig. 3.

Lepralia edax, Hincks, Brit. Mar. Polyzoa, p. 311, pl. xxiv. fig. 7, 7*a*, 8; Smitt, Floridan Bryozoa, pt. ii. p. 63, pl. xi. figs. 220–223; Waters, Quart. Journ. Geol. Soc. vol. xxxviii. p. 270.

Cumulipora angulata, Reuss, Septarienthon, p. 63, pl. viii. fig. 12.

Zoarium dome-shaped, about 30 millim. diameter, composed of many layers of zoœcia. The under surface is cupulate, and the zoœcia

here radiate in uniserial rows from the centre, with the greatest regularity, whereas on the upper suface numerous colonies are seen to start from various points of the surface. The under surface is divided by radiating and bifurcating sulci, and the part between these is raised, and along the ridges there are elevations looking like points of attachment. In this respect the dorsal surface resembles that of *Selenaria maculata*. Zoœcia very little raised, irregularly hexagonal, separated by distinct raised borders with large pores round the edge of the zoœcium; small avicularia below the aperture, with the opening rounded or slightly acute, directed downwards. Oral aperture with the proximal edge nearly straight, the distal edge rounded, formed of more than half a circle, with two contractions inside the aperture near the middle; at widest part about 0·12 mm. wide. Ovicell raised, globular.

I have already pointed out that the aperture in recent specimens is larger than in that from the Crag, and both the specimen from Mt. Gambier and this one from Murray Cliff correspond in this respect with those from Florida. In the Australian fossils no zoœcial avicularia (onychocellaria) have been found. Some ovicells show an indistinct area on the front; but this is not distinguishable on all, and the ovicell is more globular than figured by Mr. Hincks.

Mr. Busk* refers to finding "the backs of the polyzoan cells usually disposed in parallel rows, much as they are on the concave surface of some Lunulites," and Smitt seems to have noticed the same thing; it is therefore interesting to find it now in a true Lunulites-form.

38. Lepralia depressa, Busk, var.

Lepralia depressa, Busk, var.—Waters, Quart. Journ. Geol. Soc. vol. xxxviii. p. 509.

In a specimen of this variety from Aldinga there are small, globular, raised, granulated ovicells.

39. Lepralia rostrigera, Smitt.

Escharella rostrigera, Smitt, Floridan Bryozoa, p. 57, pl. x. figs. 203–205.

A specimen from the River-Murray Cliffs is growing in the Lepralia-stage. The hexagonal zoœcia are very little raised and the surface is covered with large pores. The aperture is nearly round, with two lateral contractions; width 0·14 millim. There is usually a small avicularium pointed upwards on one side of the aperture, but seldom on both sides.

Loc. Florida, 35–43 fathoms.

40. Lepralia escharella, Römer (in Vincularia-form).

Vincularia escharella, F. A. Römer, "Die Polyparien des Norddeutschen Tert. Geb." Paleontographica, vol. ix. p. 6, pl. i. fig. 1.

This is evidently allied to *L. burlingtoniensis*, but the hexagonal zoœcia are much larger, and the whole surface is covered with large pores. The oval oral aperture is larger, measuring about 0·3 millim. across.

Loc. Oligocene of Lattdorf (Römer), Aldinga.

* Crag Polyzoa, p. 59.

41. LEPRALIA BURLINGTONIENSIS, Waters, Quart. Journ. Geol. Soc. vol. xxxviii. p. 270, pl. vii. fig. 6.

42. LEPRALIA SUBIMMERSA, MacG.

Lepralia subimmersa, MacGillivray, Nat. Hist. of Victoria, Zool. decade iv. p. 23, pl. xxxv. fig. 5.

Zoarium in Eschara-form growing as solid lamellate anastomosing fronds. Zoœcia subhexagonal, bounded by prominent slightly sinuous lines; surface smooth, with large pores near the border. Oral aperture round above, concave below, with a small oral avicularium just below the aperture, sometimes in the peristome. The state of preservation does not allow of satisfactory examination of the aperture. From one broken-down ovicell it is clear that it was entirely immersed.

Loc. Living: Warrnambool. Fossil: Aldinga.

43. LEPRALIA CONFINITA, sp. nov. (Pl. VII. fig. 10.)

Zoarium in Eschara-form, flat. Zoœcia indistinct, surface with a few large pores amd small round avicularia scattered about; oral aperture round above, slightly contracted below, with a tooth on each side. The aperture (0·15–0·16 mm. wide) is surrounded by a round band. The zoœcial characters remind us of *Myriozoum truncatum*, but the cells and aperture are there larger. It is also allied to *Lepralia crassa*, Reuss, and *L. varians*, Seg. I have some flat bilaminate fragments of a similar recent *Lepralia* dredged by Mr. Brazier from Piper Island (9 fathoms), but the zoœcia are much smaller, with the aperture about 0·12 mm., and the surface is dotted over with numerous small round avicularia. Possibly they should be united, although the more robust character of the fossil makes a considerable difference in the general appearance.

Loc. Aldinga.

44. SMITTIA TATEI, T.-Woods. (Pl. VII. fig. 15.)

Eschara Tatei, T.-Woods, Trans. Roy. Soc. N. S. W. 1876, p. 3, fig. xv.

Smittia Tatei, Waters, Quart. Journ. Geol. Soc. vol. xxxvii. p. 337, pl. xvii. fig. 65, and vol. xxxviii. p. 271, pl. vii. fig. 10, pl. viii. fig. 21.

Smittia Perrieri, Jullien, Bull. de la Soc. Zool. de France, p. 19, pl. xvi. fig. 45.

There are small flattened branches from the Murray Cliffs; and from Aldinga there is a most interesting colony in which the round branches anastomose and form a reticulate mass. The diameter of the branches is about 3 millim. In this specimen there is a peristomial sinus instead of the suboral pore; but this sinus is frequently almost closed in above, and no doubt the function is the same in both cases.

Loc. Living: N.W. of Spain, 2108 metres (*Jullien*). Fossil: Curdies Creek Mt. Gambier, Bairnsdale, Waurn Ponds, River-Murray Cliffs, Aldinga.

45. SMITTIA LANDSBOROVII, Johnst.

Lepralia Landsborovii, Johnst. Brit. Zooph. ed. 2, p. 310, pl. liv. fig. 9.

The aperture of the round suboral avicularium is very small, appearing as a point or a sublunate opening. The specimen is in the Lepralia-form.

Loc. Living: British seas, Mediterranean, Florida, Australia (H.), Greenland. Fossil: River-Murray Cliffs.

46. SMITTIA RETICULATA, MacG.; Waters, Quart. Journ. Geol. Soc. vol. xxxviii. p. 272.

47. SMITTIA SERIATA, Reuss; Waters, *loc. cit.* p. 272, pl. viii. fig. 17.

48. SMITTIA MILNEANA, Busk, var. COÆQUATA, nov.

Mr. Busk described in the Crag Polyzoa a fossil as *Lepralia Edwardsiana* (p. 44, pl. v. fig. 2), but this name he subsequently changed to *L. Milneana* (p. 132). The fossils from Aldinga in general appearance more resemble *Mucronella variolosa*, but the same main characters are found in both. In both the Crag and the Australian fossils there is a broad oral plate extending nearly across the aperture, the peristome is thickened and raised, and there is a small avicularium on one side, which usually forms a peristomial sinus, but sometimes in the Australian fossils it is raised and forms a mucro. The avicularia are in both in about the same position, but in the Aldinga specimens they are not at all raised, and are rounded at both ends with a wide mandibular opening directed inwards. In the variety the zoœcia are bordered by a thick raised line, and are surrounded by a row of large pores.

Loc. The type occurs in the Coralline Crag (*B.*) and in my collection from Leiston, Suffolk. The variety is represented by two specimens, one growing on *Cellepora tridenticulata*, B., and the other on *Monoporella sexangularis*, Goldf., both from Aldinga.

49. SCHIZOPORELLA VULGARIS, Moll.

Eschara vulgaris, Moll, Seerinde, p. 61, pl. iii. fig. 10, A, B.

50. SCHIZOPORELLA SIMPLEX, Johnst. var. ALDINGENSIS.

Lepralia simplex, Johnston, Brit. Zooph. ed. 2, p. 305, pl. liv. fig. 4.

Schizoporella simplex, Hincks, Brit. Mar. Polyzoa, p. 246, pl. xxxv. figs. 9, 10.

A specimen from Aldinga varies from the British species in having no umbo, but we have in many species seen that the umbo is not a constant character, and I have therefore thought it advisable to consider it only as a variety. There are no avicularia, and the width of the aperture is 0·13 millim.

Loc. Living: British and Irish. Fossil: Scotch Glacial deposits.

51. SCHIZOPORELLA PHYMATOPORA, Reuss.

Eschara phymatopora, Reuss, Foss. Anth. & Bry. v. Crosaro, p. 272, pl. xxiiii. fig. 1.

Schizoporella phymatopora, Waters, Quart. Journ. Geol. Soc. vol. xxxvii. p. 338, pl. xv. figs. 31, 32, and vol. xxxviii. p. 510.

Myriozoum honolulense, Busk, 'Challenger' Report of Polyzoa, p. 170, pl. xxv. fig. 2.

Specimens from the River-Murray Cliffs occur as hollow cylinders of about the same size as those from Bairnsdale. The dorsal surface is divided into oblong zoœcial areas. The rosette-plates are at the base of the zoœcial wall, with, normally, two distal plates.

Loc. Fossil: Bartonian of Val di Lonte & Ferrara di Monte Baldo (Italy); Curdies Creeks; Bairnsdale and River-Murray Cliffs. Living: Sandwich Islands, 20–40 fathoms.

52. Schizoporella striatula, Smitt.

Gemellipora striatula, Smitt, Floridan Bryozoa, pt. 2, p. 37. pl. xi. fig. 207.

The surface of the specimen from the River-Murray Cliffs is smoother than in the Floridan specimens, and the pores are not so distinct; but the size is the same, with the oral aperture also 0·06 millim. wide, and there is the same characteristic prolongation of the zoœcia, with a small round opening at the end.

Loc. Living. Florida, 68 fathoms.

53. Schizoporella fenestrata, Waters.

Schizoporella fenestrata, Waters, Quart. Journ. Geol. Soc. vol. xxxviii. p. 399.

A fossil from the River-Murray Cliffs has smaller zoœcia and a smaller aperture (0·13 millim.) than the one from Curdies Creek, and should perhaps be called var. *minor*. It has the surface coarsely granular and covered with pores; the aperture is deeply sunk, and there is frequently on one side a little below the aperture an avicularium with a round aperture, which in some cells is replaced by a very large raised avicularium covering the whole cell. The opening of this avicularium is triangular, with a tooth from the cross bar, and is situated at right angles to the axis of the zoarium.

Loc. Curdies Creek; River-Murray Cliffs.

54. Schizoporella Cecilii, Aud.

Flustra Cecilii, Aud.; Savigny, Egypte, pl. viii. fig. 3, p. 66.

55. Schizoporella protensa, sp. nov. (Pl. VII. fig. 14.)

In Lepralia-form growing on *Microporella elevata*. Zoœcia regularly placed, hexagonal, slightly rounded, with a row of large pores round the edge, and with subtriangular avicularium directed outwards, on one or both sides about halfway down the zoœcium. Aperture (0·2 millim. wide) rounded at the distal end, below straight with a distinct sinus.

Loc. Aldinga.

56. Mastigophora Dutertrei, Aud.

Mastigophora Dutertrei, Hincks, Brit. Mar. Polyzoa, p. 279, pl. xxxvii. figs. 1, 2.

Specimens from the River-Murray Cliffs and Aldinga are of about the same size as these figured by Mr. Hincks, but the ovicells are

rather larger, and these are sometimes pressed in on the front, giving the appearance of a round depression; but perfect specimens seem to be globular. The surface is smooth and the peristome is but little raised. The oval aperture is about 0·12 millim. with six marginal spines. I feel some doubt about this determination, as the nature of the appendages is not distinguishable, and certainly many cells had neither vibracula nor avicularia.

Loc. River-Murray Cliffs, Aldinga.

57. Retepora marsupiata, Smitt; Waters, Quart. Journ. Geol. Soc. vol. xxxvii. p. 342, pl. xv. figs. 34–36, pl. xvii. figs. 59, 61, 76, 77; vol. xxxviii. pp. 275, 511; and vol. xxxix. p. 439, pl. xii. figs. 13 & 21.

An imperfectly preserved specimen from Aldinga was sent over by Professor Tate marked "*R. vibicata,* Sturt;" but it is impossible to make specific comparison with the fossils found by Sturt, and this does not seem to be the *R. vibicata* of Goldfuss. The ovicell has a double cleft.

58. Rhynchopora bispinosa, Johnston.

See Hincks, Cat. Mar. Polyzoa, p. 385, pl. xl. figs. 1–5.

A specimen from River-Murray Cliffs has a large avicularium raised as a mucro in front of the aperture, and frequently at the base of this on one side there is a smaller avicularium.

Loc. Living: British seas; Mazatlan; Adelaide; Victoria Bank, off S.E. Brazil, 33 fathoms (*Ridley*).

59. Cellepora coronopus, S. Wood.

Cellepora pumicosa, Linn. (non Busk), Syst. Nat. 12th ed. p. 1286.

Cellepora coronopus, S. V. Wood, Ann. & Mag. Nat. Hist. vol. xiii. p. 13; Busk, Crag Polyzoa, p. 57, pl. ix. figs. 1, 2, 3; Manzoni, Bry. Foss. Ital. Cont. 4, p. 13, pl. iii. figs. 18, 19; Waters, Ann. & Mag. Nat. Hist. ser. 5. vol. iii. p. 192.

Cellepora tubigera, Busk, loc. cit. p. 60, pl. ix. figs. 8–10.

Cellepora gambierensis, Busk, Quart. Journ. Geol. Soc. vol. xvi. p. 261 (named only, no description); T.-Woods, Geol. Obs. in S. Australia, pp. 74 & 85; T.-Woods, Trans. R. Soc. Vict. vi. p. 4, pl. i. fig. 3.

Celleporaria gambierensis, Stoliczka, Foss. Bry. der Orakei Bay, p. 141, pl. xx. fig. 7.

Although this species is reported to be extremely common in Australia, a badly preserved specimen from Aldinga, which was sent over by Professor Tate marked "*C. gambieriensis,*" is the first that I have seen, and as the descriptions laid most weight upon the colonial growth, it was impossible to make any comparisons.

It grows in solid round branches about 8 millim. in diameter, and anastomoses regularly. The aperture of the zoœcia is round, about 0·13–0·20 millim., with a small avicularium, apparently below the mouth. No zoœcial avicularia or ovicells have been found on the specimen.

Stoliczka (*loc. cit.* p. 142) suggested that probably the fossil was *C. coronopus*; and so far as this specimen permits a judgment, I certainly agree with him.

Loc. Living: Coasts of Britain and France; Mediterranean. Fossil: Pliocene: Crag; Pliocene of Italy and Sicily; Mt. Gambier (*B.*); Geelong (Wilkinson); Orakei Bay (New Zealand); Aldinga.

60. Cellepora avicularis, Hincks.

Cellepora Redoutei, Aud. in Sav. Egypte, pl. vii. fig. 6, p. 64.

Cellepora ramulosa, form *avicularis*, Smitt, Oefv. Kon. Vet.-Akad. Förh. 1867, Bihang, pp. 32 & 194, pl. xxviii. figs. 202–210.

Cellepora avicularis, Hincks, Q. J. Micr. Soc. viii. p. 278; Ann. & Mag. Nat. Hist. ser. 3, vol. ix. p. 304, pl. xii. fig. 6; Brit. Mar. Polyzoa, p. 406, pl. liv. figs. 4–6; Norman, B. Assoc. Rep. 1868, p. 308; Waters, Ann. & Mag. Nat. Hist. ser. 5, vol. iii. p. 193, pl. xiv. figs. 11, 12.

A specimen from the River-Murray Cliffs apparently grew over the stem of some seaweed, and rises into irregular nodulations. The zoœcia are ovate with an avicularium at the side by the lower part of the oral aperture; oral aperture suborbicular, angular at the proximal edge, forming a sinus; large spatulate avicularia distributed over the zoarium. Ovicell globose with large punctures.

The size of the cells, apertures, and avicularia is the same as in my Naples specimens.

Loc. Living: British seas; Arctic Ocean; Red Sea; Naples; 10 fathm. Fossil: River-Murray Cliffs.

61. Cellepora costata, MacG.

Cellepora costata, MacG. Trans. R. Soc. Vict. 1869, p. 11.

Cellepora retusa, Manz., var. *caminata*, Waters, Ann. & Mag. Nat. Hist. ser. 5, vol. iii. p. 194, pl. xiii. fig. 1.

A small badly preserved specimen from Adelaide is growing on *Microporella ferrea*, W. This has smaller zoœcia than a recent specimen from Glenelg, S. Australia, in which the aperture is 0·13 millim., while in the fossil it is only 0·1 millim. In the fossil no ovicells are preserved, and the avicularia do not rise above the zoœcia, whereas in the recent specimen the ovicells are the same as those from Naples, and the avicularia, although they turn more inwards, closely resemble those from Naples.

This I believe is related to *Lagenipora spinulosa*, Hincks.

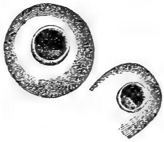
Loc. Living: Wilson Promontory and Queenscliff, Victoria (*MacG.*); Glenelg, S. Australia (*A. W. W. coll.*). Fossil: Leithakalk of Nussdorf (Vienna) (*A. W. W. coll.*), Adelaide.

62. Cellepora divisa, sp. nov.

The zoarium is subglobular, 6–8 millim. in diameter. The zoœcia are small and irregular in shape, with a small round aperture 0·13 millim. wide, and inside this there is a plate extending about one third across the aperture (fig. 1). There is a central "pit" round

which the zoœcia are formed, and in this respect and the shape and size of the zoœcia it much resembles *C. fossa*, Haswell; but no avicularia are found on the colony. I have a small globular colony (4 millims. diam.) from the Crag of Leiston, with the oral apertures of about the same size, and a similar plate directed inwards. This

Fig. 1.—*Zoœcia of* Cellepora divisa, *sp. n., showing apertures.* (Enlarged 25 diam.)



Crag fossil has a rostrum below the aperture with a terminal avicularium, and has plain globular ovicells. Possibly this is the armed condition of the present species.

Loc. Mt. Gambier.

63. Cellepora mamillata, Busk.

Cellepora mamillata, Busk, Cat. Mar. Polyzoa, p. 87, pl. cxx. figs. 3, 4, 5; Ridley, Proc. Zool. Soc. 1881, p. 54.

Cellepora mamillata, var. *atlantica,* Busk, Chall. Rep. Polyzoa, p. 199, pl. xxxv. figs. 4, 5, 13.

In a specimen from the River-Murray Cliffs the zoarium incrusting a shell is raised into large prominent mamillations. Oral aperture nearly round, flattened below, about 0·18 millim. diameter. Avicularia projecting above the zoœcia, with large triangular mandibular openings on the median line on the internal aspect.

The mamillation of the zoarium occurs in a very large number of *Celleporæ* and cannot be looked upon as a character of specific value. *C. mamillata* only differs from *C. pumicosa*, Busk, in the shape of the aperture.

Loc. Living: Coast of Patagonia; Victoria Bank, S.E. Brazil; Crozet Island, off Bahia; New Zealand (*Hutton*); Victoria (*MacG.*). Fossil: River-Murray Cliffs.

64. Cellepora albirostris, Smitt.

Discopora albirostris, forma typica, Smitt, Floridan Bryozoa, p. 70, pl. xii. figs. 234–239.

Cellepora albirostris, Busk, Journ. Linn. Soc. vol. xv. p. 347; ‘Challenger’ Report on the Polyzoa, p. 193, pl. xxxiv. fig. 7, pl. xxxv. fig. 3.

A specimen from the River-Murray Cliffs is dome-shaped, resembling *Lunulites*. The zoœcia are round, much raised, and smooth; below the oral aperture there are small oral avicularia with rounded openings, but I do not find any vicarious avicularia (onychocellaria); above the aperture there are two spines; aperture

rounded on the distal edge, becoming wider on the proximal, which is slightly concave 0·14–0·17 millim. wide. In the recent and fossil specimens there are at the two sides of the aperture small teeth, one on each side directed downwards towards the neural wall. The shape of the operculum indicates the presence of such teeth, but they have been overlooked. The dorsal surface much resembles that of *C. biradiata*, W., and this species, *C. albirostris*, *C. pertusa*, and *C. tridenticulata*, are no doubt allied.

The specimen that I referred to *pro tem.* as *C. repleta* (Journ. Roy. Micr. Soc. vol. ii. p. 392, pl. xv. figs. 6, 8), is *C. albirostris*, and grows round the stalks of seaweed, rising into ridges with zoœcia on each face of the ridge. These have no oral spines, frequently the rostrum bifurcates, and ovicells surmounted with small avicularia are supported by the rostrum. Smitt refers to the Floridan specimens sometimes having two spines and sometimes being without; and as this is made a leading distinction between *C. albirostris* and *C. hastigera*, I should certainly feel inclined to unite them, for in each colony of *C. albirostris* there is great variation in the size and form of the rostral process.

We see in this species and *C. tridenticulata* how little importance we should attach to the mode of growth; and among specimens picked up at the same time near the Semaphore, Adelaide, as being the same species, we have found that although they most closely resembled one another in general appearance, they represent *Heteropora crevicornis*, d'Orb., *Cellepora albirostris*, and *C. tridenticulata*.

Loc. Living: Florida, 25–35 fathm.; Sydney (*Sm.*); Heard Islands, 75 fathm. (*B.*); Semaphore, Adelaide (*A. W. W. coll.*). Fossil: River-Murray Cliffs.

65. CELLEPORA PERTUSA, Smitt.

Discopora pertusa, Smitt, Floridan Bryozoa, p. 72, pl. xii. figs. 240, 241.

A specimen from Aldinga is irregularly subglobular; diameter 4 to 7 millim. In the shape of the zoœcia and of the large oral apertures it corresponds with the Floridan specimens; but in the fossil there are no avicularia, and from Smitt's figures the avicularia only seem to occur on some of the zoœcia. Oral aperture 0·28 millim.

Loc. Florida, 35–60 fathm.

66. CELLEPORA PERTUSA, Sm., var. LIGULATA.

The zoarium consists of hollow cylindrical branches. The zoœcia are ovate, elongate, irregular, with a rounded aperture nearly straight below and slightly contracted at the sides; there is a very minute avicularium below or to the side of the aperture, and besides this there are frequently small ligulate or spatulate avicularia on the zoœcia, and here and there an elongate spatulate vicarious avicularium. The oral aperture is 0·12 millim.

I feel much doubt about any determination of this form, but in calling it a variety of *pertusa* the similarity in most points is indi-

cated, but the minuteness of the aperture and the avicularia on the front of the zoœcia distinguish it.

Loc. River-Murray Cliffs.

67. Cellepora biradiata, sp. nov. (Pl. VII. figs. 11, 12.)

In a specimen from the River-Murray Cliffs the zoarium is conical, mamillated, in diameter about 20 millim., and has the general appearance of a large *Lunulites.* The zoarium is formed by many superposed layers of zoœcia. On the dorsal surface there are radiating lines, and when the outer surface is broken away, the walls of a double row of zoœcia are seen, and each such double row is separated from its neighbours by septa (fig. 11).

Zoœcia irregular, subglobular, raised, with the oral aperture rounded on the distal edge, nearly straight on the proximal, forming more than a semicircle, 0·12 millim. wide. Below the aperture, a little to one side, is a small raised avicularium, with the mandibular opening forming a nearly equilateral triangle. In one specimen there are two spatulate avicularia, and sometimes three rudimentary teeth can be distinguished in the oral aperture; but this is exceptional. Ovicells subglobose, broader than high, smooth, resembling the ovicells of *Cellepora ramulosa*, L., as figured by Hincks, Brit. Mar. Polyzoa, pl. lii. fig. 8.

This and *C. compressa*, Busk, *C. tridenticulata*, B., and *C. albirostris*, Sm., all seem closely related.

68. Cellepora tridenticulata, Busk.

Cellepora tridenticulata, Busk, Journ. Linn. Soc. vol. xv. p. 347; 'Challenger' Report on the Polyzoa, p. 198, pl. xxix. fig. 3, pl. xxxv. fig. 17.

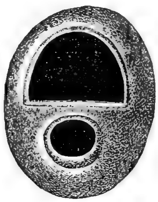
From the River-Murray Cliffs there is a solid dome-shaped colony formed of many layers, measuring about 25 millim. in diameter, and in a colony from Aldinga the zoarium commenced in a dome shape, then spread out to about 10 centim. in diameter and grew into a solid mass 10 centim. high. The zoœcia are irregular, immersed, with the oral aperture straight below, rounded at the distal end, forming a little more than half a circle, and a little way down the aperture on the proximal edge there are three narrow teeth directed forwards. Below the oral aperture there is a small rounded avicularium, and there was a spine on each side of the aperture. Oral aperture about 0·2 millim., from which it can be seen that in the fossil it was larger than in the specimen described by Mr. Busk; but recent specimens from the Semaphore, Adelaide, correspond with the fossil. On the under surface the elongate hexagonal shape of each cell is visible, and there are projections for attachment. Out of several fossil specimens I have only found two with a vicarious avicularium (onychocellarium), and in this case it was spatulate, as figured by Mr. Busk. In recent specimens sometimes the avicularium is very small, at others it rises into a large rostral process, and occasionally there are four teeth in the oral aperture. *C. tridenticulata* and *C. honolulensis*, B., are very closely allied.

Loc. Living: Off Cape York, lat. 10° 30′ S., long. 142° 18′ E., 8 fathm. (*B.*); Semaphore, Adelaide (*A. W. W.*). Fossil: Aldinga, River-Murray Cliffs (dome-shaped and incrusting); Yorke's Peninsula (irregular cone-shaped); Waipukerau (New Zealand).

69. Cellepora fossa, Haswell, Waters, Quart. Journ. Geol. Soc. vol. xxxvii. p. 343, pl. xviii. fig. 89, and vol. xxxviii. p. 275.

From the River-Murray Cliffs there is a specimen about 25 millim. in diameter, with the one surface, which may be called the under surface, flat; the other is slightly rounded. On the flat surface there are about forty well-marked pits and a few smaller ones.

Fig. 2.—*Zoœcium of* Cellepora fossa. (Enlarged 25 diam.)



Mr. Haswell, in a "Note on a curious instance of Symbiosis" (Proc. Linn. Soc. N. S. Wales, vol. vii. 1882), refers to his discovery of small red Actinids lodged in cylindrical pits in recent *Cellepora*, and he attributes these pits in *C. fossa* to a similar parasite. It is therefore extremely interesting to frequently find similar pits in fossil *Celleporæ*. Mr. Busk refers to a perforation two thirds through *C. tubulosa*, a fossil from Australia, which, however, cannot be identified, as the description only takes cognizance of the mode of growth.

The straight edge of the aperture is irregularly rough, but there are no teeth.

Loc. Living: Holborn Island. Fossil: Curdies Creek, Mt. Gambier, River-Murray Cliffs, and Aldinga.

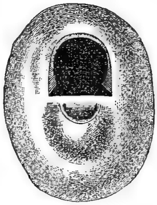
70. Cellepora fossa, Hasw., var. marsupiata, nov.

Zoarium subglobular (6 millim. diam.), with a central pit as in *C. fossa*. In the typical *C. fossa*, the avicularium is very large, often nearly as large as the oral aperture (fig. 2), so that in badly preserved specimens the appearance is of one large round aperture with a bar across. In the present variety the avicularium is much smaller, with the avicularian chamber raised, forming a kind of pouch with a semicircular aperture (fig. 3). Surface granular. The oral aperture (0·1–0·12 millim.) is narrower than in *C. fossa* but is proportionately longer; inside the aperture directed downwards, towards the interior of the zoœcium, there is a tooth on each side of the aperture, and sometimes these teeth are continued as a plate round the proximal part of the aperture. In a few cases faint traces of

such teeth can be detected in the typical *C. fossa*, but this is exceptional.

Loc. River-Murray Cliffs.

Fig. 3.—*Zoœcium of* Cellepora fossa, *var.* marsupiata. (Enlarged 25 diam.)



71. Lekythopora hystrix, *MacG.*

Lekythopora hystrix, MacGillivray, "Descriptions of New or Little-known Polyzoa," pt. iii. p. 194, Trans. Roy. Soc. Vict. vol. xix. pl. i. fig. 6; also pt. viii. p. 8, pl. ii. fig. 6 (advance copy).

In the growth and the shape of the cells this so much resembles various Cyclostomata that until sections were prepared I did not recognize that it was a Chilostoma; and even after careful examination the fossil remains very incomprehensible, and further study of recent specimens is much to be desired. The state of fossilization is not favourable for studying the minute structure. The zoœcia, which are subtubular, open only on one side of the zoarium, and are erect and often more or less in bundles, giving the appearance of *Frondipora*. The small opening on the side of the aperture which MacGillivray describes as an avicularum, is only distinguishable in a few cases. On the front of the zoarium there are a number of globular mamillations, sometimes with a small opening in the centre. These much resemble the enlargements on the front of the cell which Professor MacGillivray describes as ovicells; but these enlargements in the fossil are usually entire, with comparatively large pores on the surface. The solid under surface of the zoarium has a few irregularly scattered large-sized pores.

72. Cupularia canariensis, Busk.

Cupularia canariensis, Busk, Q. J. Micr. Soc. vol. vii. p. 66, pl. xxiii. figs. 6–9; Crag Polyzoa, p. 87, pl. xiii. fig. 2; Manzoni, Foss. Ital. Contrib. i. p. 10, pl. ii. fig. 17; Bri. foss. del Mioc. d'Aust. ed Ungh. p. 24, pl. xvii. fig. 56.

Membranipora canariensis, Smitt, Floridan Bryozoa, pt. 2. p. 10, pl. ii. figs. 69–71.

Specimens from Aldinga have larger zoœcia and larger opesial openings than some recent specimens from Princess Charlotte Bay. In the recent one the sulcate structure of the under surface is very marked; but upon careful examination faint cross-divisions can also be distinguished, thus separating the dorsal surface into zoœcial

divisions, while in the fossil the dorsal sulci are not very marked, and there are but few pores in each quadrangular division; again they are more numerous in the Charlotte-Bay example. The difference between this and *C. guineensis* and *C. stellata* consists in the lamina not extending up to the distal border; but this is a variable character, and probably all three should be united under one name.

Loc. Living: Madeira and Canaries; Princess-Charlotte Bay (sent by Mr. Brazier); Florida, common, 10–44 fathm. (*Sm.*). Fossil: Miocene—Austria and Hungary. Pliocene, Crag—Hills of Pisa, Castelarquato, Asti, Mt. Mario, Rhode Island; Tortonian and Saharian of Reggio (Calabria) (*Seg.*); Aldinga.

73. Selenaria maculata, Busk.

Selenaria maculata, Busk, Cat. Mar. Polyz. p. 101, pl. cxvii.; Waters, Quart. Journ. Geol. Soc. vol. xxxix. p. 440, pt. xii. figs. 7, 9, and 12.

A specimen from the River-Murray Cliffs is about 6 millim. in diameter, and is exactly similar to specimens from Muddy Creek and Bird Rock. The dorsal surface is divided by radiating ridges, between which there are single or double rows of large pores. Another specimen from Aldinga (sent over as *Lunulites rutella*) has smaller zoœcia and very few vibracular chambers, and on the dorsal surface there are, instead of the large pores, long erect tubes, which may serve for attachment.

Besides the species named there is a small cylindrical fragment of what I believe is *Lepralia* (*Onchopora*) *immersa*, Haswell; but with so small a piece, imperfectly preserved, I cannot feel sure of the determination. The collection also contains a *Membranipora* from the River-Murray Cliffs which belongs to the *M.-spinifera* group, and another with oval opesia and a small avicularium above the opening, which might be *M. levata*, Hincks.

Upon reexamining the Mt.-Gambier collection I find that a specimen which I thought was *Retepora rimata*, W., is *R. jacksoniensis*, Busk ('Challenger' Report, p. 125, pl. xxvii. fig. 4). These two species are very closely allied, but the avicularia differ in shape. A further study as to the range of variability of *R. jacksoniensis* would be of great interest.

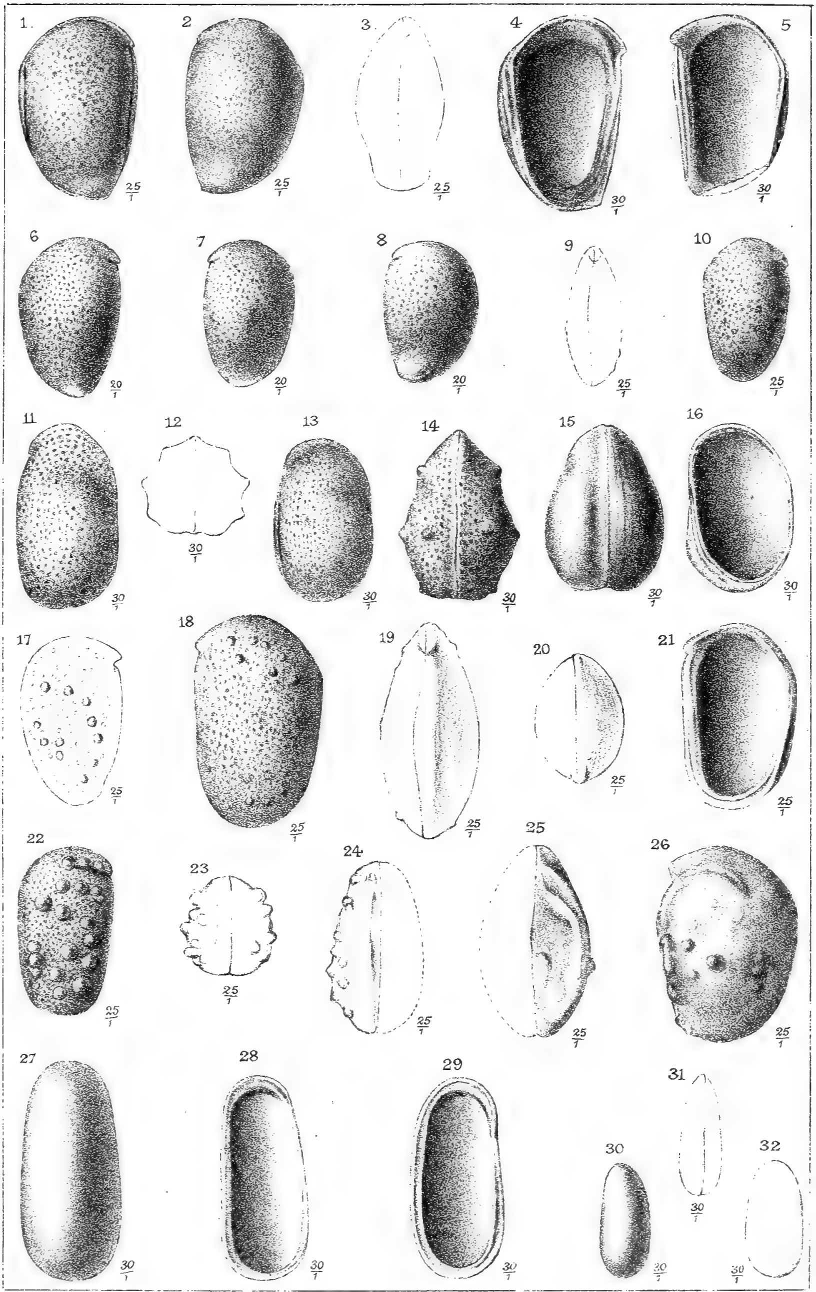
EXPLANATION OF PLATE VII.

Fig. 1. *Membranipora rhynchota*, Busk. The zoœcia on the left have ovicells; those on the right are without.
2. *Monoporella sexangularis*, Goldf. From specimen fig. 13.
3. *Membranipora aperta*, Busk.
4. *Micropora patula*, Waters.
5. *Membranipora parvicella*, T. Woods.
6. *Microporella elevata*, T.-Woods; showing marginal avicularia.
7. *Microporella magna*, T.-Woods.

Fig. 8. *Microporella pocilliformis*, sp. nov.
9. *Microporella elevata*, T.-Woods; drawn from the same colony as No. 6.
10. *Lepralia confinita*, sp. nov.
11. *Cellepora biradiata*, sp. nov.; dorsal surface.
12. Ditto, natural size.
13. *Monoporella sexangularis*, Goldf.; natural size.
14. *Schizoporella protensa*, sp. nov.
15. *Smittia Tatei*, T.-Woods; natural size.
16. *Membranipora temporaria*, sp. nov.

Discussion.

Mr. Etheridge said the author had done valuable service in describing Polyzoa from various countries, and this contribution would doubtless prove a valuable addition to our knowledge.



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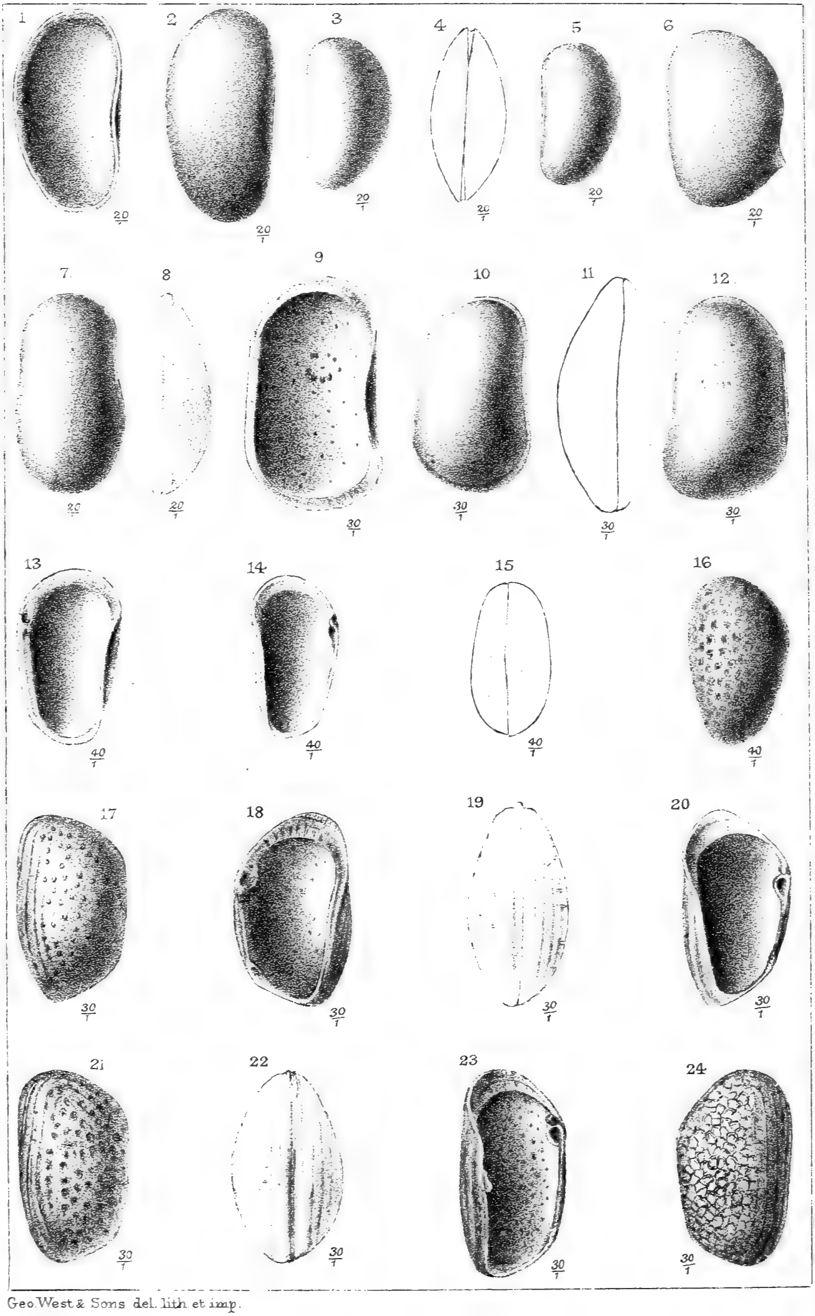
PURBECK OSTRACODA.



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PURBECK - OSTRACODA.

29. *On the* Ostracoda *of the* Purbeck Formation; *with* Notes *on the* Wealden Species. By Prof. T. Rupert Jones, F.R.S. F.G.S., &c. (Read May 13, 1885.)

[Plates VIII. & IX.*]

Contents.

§ I. Introduction.

In the 'Geological Magazine,' dec. 2, vol. v. (March and June 1878), pp. 103 & 277, I offered some observations on the Ostracoda of the Purbeck and Wealden Formations, and endeavoured to determine the species already described and figured by Sowerby, Fitton, F. A. Römer, and W. Dunker, and by E. Forbes, Lyell, and P. de Loriol. One of these species was further noticed (as *Cythere? purbeckensis*) in the 'Proceedings of the Geologists' Association,' vol. viii. 1883, p. 58, together with an additional species which I had defined as *Cythere boloniensis*† [*bononiensis*] in the Bull. Soc. Géol. France, ser. 3, vol. viii. 1882, p. 616.

* These Plates have been drawn by aid of a grant from the Royal Society, for the illustration of Fossil Entomostraca.

† Now corrected to *bononiensis*, in accordance with the Latin name of Boulogne, "*Bononia*."

Having been enabled, by the help of the Rev. O. Fisher, Mr. W. Cunnington, Mr. Horace B. Woodward, Mr. J. C. Mansel-Pleydell, Prof. J. F. Blake, and other friends, to add considerably to my own collection of Purbeck Entomostraca, among which are many specimens collected by Fitton and Brodie, and having been kindly aided in my practical work by Mr. E. T. Newton, F.G.S., and Mr. C. D. Sherborn, I have begun to examine and determine the whole series of Ostracodous species characteristic of the Purbeck-Wealden beds. As far as opportunities have offered, I have also studied the specimens preserved in other collections and museums.

§ II. The Ostracoda of the Purbeck Beds.

Sources of Information.

Professor Edward Forbes commenced this work of determining the Purbeck Ostracoda long ago*; but his results were not fully recorded, nor, indeed, is it now possible (as already intimated in the papers referred to above) to recognize each of the typical specimens he intended to be preserved, or all the species that he intended to determine, although a near approximation, on the whole, has been obtained.

The chief aids in this inquiry have been:—(1) The woodcut figures in Sir Charles Lyell's 'Manual of Elementary Geology,' 5th edit. 1855, and in later editions, copied presumably from diagrams made (between 1851 and 1855) for Prof. E. Forbes by his brother, James Forbes, for his lectures at the Museum of Practical Geology; (2) Some of these diagrams now remaining in that Museum; (3) Some hand-specimens in the same Museum, with names given by E. Forbes attached to them; (4) Two MS. notes, containing rough sketches by E. Forbes, one not fully dated, but probably written on July 18th, 1851, and sent to Mr. Bristow (with which he has most kindly favoured me), and the other to myself, dated July 23rd, 1854.

Sir C. Lyell's Woodcuts, and the Diagrams at the Museum of Practical Geology.—From the figures and accompanying remarks in Lyell's 'Manual' &c., 1855, p. 294 &c., and the next edition of the same work, with the title of 'Elements of Geology,' 6th edition, 1865, pp. 378 & 387, we find that

1. "*Cypris*† *gibbosa*," fig. 368, *a*,
2. "—— *tuberculata*," fig. 368, *b*,
3. "—— *leguminella*," fig. 368, *c*,

are referred to the "Upper Purbecks;"

* Report Brit. Assoc. for 1850, Trans. Sect. pp. 79–81; and Edinb. New Phil. Journ. vol. xlix. 1850, pp. 311–313. No names of the species are given in either of these publications.

† "*Cypris*" is far from being the genus to which all these Ostracoda are really referable. The generic relationships will be discussed later on in this paper. On these points my friend Dr. George S. Brady has favoured me with his advice and opinion.

4. " *Cypris striatopunctata*," fig. 371, *a*,
5. " —— *fasciculata*," fig. 371, *b*,
6. " —— *granulata*," fig. 371, *c*,

are referred to the " Middle Purbecks;" and

7. " *Cypris purbeckensis*," fig. 375, *a*,
8. " —— *punctata*," fig. 375, *b*,

are referred to the " Lower Purbecks."

All of these species, except *granulata** (fig. 371, *c*), were referred to " E. Forbes " by Lyell; presumably, however, *tuberculata* is after Sowerby, and *striatopunctata* was named probably after Römer, but erroneously. The woodcuts, and the remaining few of the diagrams from which they were probably reduced, are very unsatisfactory illustrations of these Ostracods, several essential features not being shown in the oblique and clumsy drawings; and in some cases probably waterworn or weathered specimens have been taken for types. This is especially noted in Proc. Geol. Assoc. vol. viii. 1883, p. 58, as regards fig. 375, *a*, which is comparable with only one individual on the slab of Purbeck limestone, XB$\frac{4}{7}$, in the Museum of Practical Geology, probably examined by E. Forbes, and that is a waterworn or weathered little " specimen, in which the valve lying uppermost has been worn or dissolved away by water so far as to leave the edge of the underlying valve exposed all round it, and like a marginal rim belonging to it."

Of the foregoing list, No. 1 is not readily recognizable, and is not noticed in the MS. note of July 23, 1854 (hereafter mentioned); but it is probably a variety of *punctata*, and, like that, most common in the upper part of the series. To this conclusion, Forbes's letter to Mr. Bristow (July 18, 1851) and the study of *punctata* and its variations easily lead me, having in view a large series of Purbeck specimens. No. 2 is met with rarely in the Middle and Upper stages of the Purbeck formation. No. 3 is easily recognized in the Middle, and occurs also in the Upper beds.

No. 4. The form here intended is rare; it is better figured in the sketch in the letter to Mr. Bristow. It is found in the Middle Purbeck. No. 5 is very characteristic of the Middle Purbeck (as is also noted by E. Forbes, and known to the Rev. O. Fisher and Mr. W. Cunnington), both by its abundance there and its absence from the other divisions of the series. No. 6. This, if intended for the *granulosa* of Sowerby, is not that species. Most probably it is the *granulosa* of Römer and Dunker, which is rare (as *Dunkeri*, see p. 339) in the Middle and Upper Purbecks.

No. 7 is the characteristic Lower-Purbeck form; and, although badly drawn in fig. 375, *a*, it is well known to the Rev. O. Fisher and Mr. W. Cunnington by direct information from E. Forbes, and is plainly indicated in his letter to Mr. Bristow. No. 8 is different from any Lower-Purbeck† species, and, indeed, is recognizable as an

* Referred to " Sowerby." It is not, however, the *granulosa* of Sowerby, but is rather the *granulosa* of Römer and Dunker, which I now term *Dunkeri*.

† Although this form occurs in the so-called " Lower Purbeck " of Swindon, we must remember that the whole of the series (Upper, Middle, and Lower) is represented there. (See further on, p. 331.)

abundant and characteristic Upper-Purbeck species and the predecessor of *Cypridea valdensis* of the Wealden formation. It is mentioned in the Cat. Foss. Mus. Pract. Geol. 1865, as belonging to the Upper Purbeck, probably by mistake.

E. Forbes's Letter, July 18, 1851.—The sketches in E. Forbes's letter to Mr. Bristow, dated only "Friday, 18th," but, from internal evidence, written in July 1851, are:—

I. For the Upper Purbeck:—1. "*Cypris spinosa*: a large black *Cypris* in some beds, with very prominent spines." This is probably an exaggerated form of *Cypridea tuberculata* (Sow.), which in some cases has larger tubercles than in others. 2. "A usually dark or black species, smooth to the eye, but really punctate; *C. gibbosa*, perhaps identical with *C. valdensis*." This I take to be E. Forbes's *punctata* and its variety *gibbosa*. 3. "A very small fellow, like snail's dung, shaped like a pea-pod." This is called "*C. leguminelloides*," and is evidently the *leguminella* of Lyell's list.

II. In the Middle Purbeck:—1. "A granulated species; scarce: *C. granulosa*." Not the *granulosa* of Sowerby, though evidently thought to be so here and when given as *granulata* in Lyell's list (1855) and in the MS. note of 1854. 2. "*C. fasciculata*. A fasciculated species, perhaps a variety of *granulosa*; with two little bundles of tubercles, one at each end. This is the most characteristic Middle-Purbeck species." It is the *fasciculata* of Lyell's fig. 371, *b*; and it is essentially the same as *Cypridea granulosa* (Sow.). 3. "An oblong species, with punctations and striations both; *C. striatopunctata*. This is rare, and only in the 'Intermarine Beds.'" Probably named after Römer's *striatopunctata*, but it matches neither Römer's nor Dunker's figures and descriptions, and Prof. Dr. Dunker* believed it to be different. 4. "I have notes also of a peapod-shaped species, larger than that of the" [*leguminelloides*]. This larger peapod-form is probably my *Cyprione Bristovii*.

III. "In the Lower Purbeck the Cyprides are all smooth and oblong†, and rather fat: *Cypris purbeckensis*." This sketch is free from the false margin referred to above (p. 313).

E. Forbes's Letter to T. R. Jones.—In his note of July 23, 1854, Prof. E. Forbes informed me whereabouts the Purbeck "Cyprides" were to be found (just about as now) in the Museum at Jermyn Street, and enumerated the following names, as "given to the principal ones," together with small rough sketches:—

"*Cyp. tuberculata*?,
—— *leguminella*,
—— *granulata*,
—— *fasciculata*,
—— *punctata*,
—— *purbeckensis* (smooth),
—— *striatopunctata*."

* In letter. (See further on, p. 319, *note*.)

† By these two features *C. punctata* is shut out from the Lower Purbeck, in which Bristow (in Damon's 'Geology of Weymouth' &c., new edition) and Lyell give it by mistake.

There is no special order kept in this list. The false margin is partly indicated for *purbeckensis,* and the name *granulata,* as in Lyell's list (fig. 371, *c*), is probably given by mistake for *granulosa* of Römer and Dunker.

The Vertical Sections published by the Geological Survey.—Only three "Cyprides" with specific names (*tuberculata, leguminella,* and *purbeckensis*) are affixed to any particular bed in the Geological Survey's "Vertical Sections" (Sheet No. 22) of the Purbeck strata, made after Prof. E. Forbes had finished his survey-work. In the successional table of the strata seen at Durlston Bay there are six Cypridiferous beds, or groups of beds, indicated for the "Upper Purbeck," the topmost containing "*C. tuberculata*;" for the "Middle Purbeck" twelve such beds; and for the "Lower Purbeck" two such special zones. Among the strata seen at Worbarrow Bay there are indicated one such bed for the "Upper," two for the "Middle," and five for the "Lower Purbeck;" at Mewps Bay, one for the "Upper," three for the "Middle," and three for the "Lower Purbeck." For the section at Ridgway Hill, north of Weymouth, there are two such zones in the "Upper;" four in the "Middle," in one of which "*C. leguminella*" is named; and six in the "Lower Purbeck," in the uppermost of which "*C. purbeckensis*" is mentioned.

The persistency of several of these Cypridiferous zones throughout the Dorsetshire sections is very noteworthy. How far the same species of Ostracoda hold their own along these zones is not yet determined; but possibly the appended lists (though imperfect) will throw some light on this subject.

Lists of Purbeck Strata by H. W. Bristow, J. H. Austen, and O. Fisher.—In Mr. Bristow's Purbeck list, in the new edition of Damon's 'Geology of Weymouth' &c., 1884, pp. 202, 207, & 209, the species referred to the three divisions of the Purbeck series are the same as in Lyell's 'Manual' above quoted. No "Cyprides" are specially mentioned in the Rev. J. H. Austen's list* in his 'Guide to the Geology of the Isle of Purbeck' &c., 1852; or in the Rev. O. Fisher's list of the strata at Swanage Bay, Trans. Camb. Phil. Soc. vol. ix. p. 568 &c., 1855; but in his list of the strata at Ridgway Hill, "*Cypris purbeckensis*" is affixed to one of the Lower Purbeck beds. Both the Rev. O. Fisher and Mr. Cunnington have favoured me with named specimens of *C. purbeckensis* and *C. fasciculata.*

Fitton and Sowerby; and Dr. Fitton's Specimens in the Museum of the Geological Society.—Of the Cypridæ referred by Fitton in 1836 to the Purbeck formation, unfortunately we cannot speak with full certainty.

Cypridea valdensis (Fitton), first and erroneously referred by J. de C. Sowerby to *Cypris faba,* Desmarest, was figured and described by him (1824) in the 'Mineral Conchology,' pp. 136–138,

* In G. Wilson and A. Geikie's 'Life of Edward Forbes' (1861) it is suggested, at p. 477, note, that this list was based on information obtained from the Geological Surveyors.

pl. 485, and the figure is very characteristic of a *Cypridea* common in the Weald Clay, as mentioned by Sowerby. This same species was referred to, and named *Cypris valdensis*, by Dr. Fitton in the Trans. Geol. Soc. ser. 2, vol. iv. 1836, pp. 177, 205, & 228, and by Sowerby at p. 344; but unfortunately another form was confused with it and figured (pl. 21. fig. 1) instead of it. Whether this other species was obtained from the Wealden or from the Purbeck beds is not evident from the memoir. At pp. 229 & 260 *C. valdensis* is also referred to as occurring in the Purbeck beds; but, in the first place, I did not meet with it, after long and careful search in that formation, until lately, when it turned up, quite rare, in one thin bed of the Middle Purbeck at Ridgway; and, secondly, hand-specimens* collected by Dr. Fitton and marked "*C. faba*" (which was at that time regarded as the same) really contain *C. purbeckensis*, and not *C. valdensis*. Fitton's fig. 1 comprises five sketches, namely:—(1) a piece of black shale crowded with Cyprids; (2) an individual of the natural size; and (3) three views of a specimen quite different from the real *C. valdensis*. Believing that I found some specimens like the fig. 1 above mentioned in the Weald Clay of Peasemarsh, Surrey, and in the Ironstone of Shotover, I separated this form as *Cypridea Austeni* in 1878 (Geol. Mag. dec. 2, vol. v. pp. 110, 277).

Fitton's fig. 2 (pl. 21) comprises two species under one name:—*b* and *c* are *Cypridea tuberculata* (Sowerby, in Fitton's memoir), and *a* is *C. Fittoni* (Mantell), both from the Weald Clay (pp. 177, 205, 228, & 345). Fig. 3 is *Cypridea spinigera* (Sowerby), from the Weald Clay (p. 345). Fig. 4, termed "*Cypris granulosa*" by Fitton and Sowerby (pp. 177, 260, and 345), is an important species, one of the modifications of which is the *Cypridea fasciculata* (Forbes), very common in the Middle-Purbeck beds. The little Cypridiferous light-coloured block figured resembles a bit of the common soft whitish Purbeck limestone, or calcareous shale, often full of *C. fasciculata*; and the two views of the bivalved carapace show the surface to be, as usual, nearly bare of tubercles about the middle region. The *notch* was missed by the artist, and the outline not quite accurately given. This species is quoted, at p. 177, from the "ferruginous sand, Tilgate Forest" (Mantell's Collection); but of this locality for it I have no certainty, and, indeed, *C. tuberculata* was probably mistaken for *granulosa*, as was decidedly the case with a specimen collected by Dr. Mantell, and now in the British Museum. The localities given at p. 260—"between Dallard's Farm and Catherine Ford" and at "Dashlet, between Penthurst and Teffont"—are doubtlessly true for this species.

The figures given by Sowerby for Fitton's memoir approach very closely *C. fasciculata* (E. Forbes), as intimated above; and, indeed, Forbes (in the letter to Mr. Bristow) refers his *fasciculata* with some doubt to *C. granulosa* (meaning, no doubt, Sowerby's species, though the sketch does not agree with it) as a variety of that species. Forbes's *fasciculata* does not occur in the Wealden beds;

* Such as those referred to at pp. 259, 260, of Fitton's memoir.

but a form resembling our figs. 10 and 17, Pl. IX., is figured by Römer (badly) and by Dunker from the Wealden of Obernkirchen and the Purbeck limestone of the Deister, as *C. granulosa*, Sow.; and Forbes's MS. sketch of *granulosa* (in Mr. Bristow's letter) also approximates to fig. 17, Pl. IX.

Among Dr. Fitton's collection deposited in the Museum of the Geological Society, there are mounted specimens of the *C. tuberculata*, fig. 2 (pl. 21), and *C. spinigera*, fig. 3, both Wealden species. There are none mounted, however, of the forms represented by his figs. 1 & 4; but specimens like fig. 4 occur freely in some of the rock-specimens preserved in that collection.

For the specific names of the Cypridæ mentioned and figured in Dr. Fitton's memoir (1836) in only one case I refer to Fitton as the authority. He especially states that he gives the name *valdensis* at p. 177; but the other species were determined by J. de C. Sowerby, and to him I refer as their authority, as, indeed, does Dr. Dunker, though F. A. Römer regarded them as Fitton's species.

Interesting notes on the casts of "*Cypris*" observed in the Lower-Purbeck beds, overlying the Portland Stone at Portland, are given at pp. 219 & 229 of Dr. Fitton's memoir "On the Strata below the Chalk" &c., Trans. Geol. Soc. ser. 2, vol. iv. (1836); but their importance is much lessened by the absence of definite descriptions and figures. A species said to be near to *C. spinigera*, and one with a "protuberance at the end of the valves," are indicated. At p. 212 "*C. tuberculata*" and "*C. valdensis*?" are also referred to as occurring at Portland, about 20 feet above the Portland Stone*. The specific determinations of these little organisms, however, were in many cases inaccurate in those days. The Cypridiferous beds in the Purbeck of Bucks are noticed at p. 297; of Wilts at pp. 259 & 260; of Dorset at p. 229.

Other Collections.—The Purbeck specimens in the Museum of Practical Geology and the British Museum have also been carefully examined. The results are incorporated with the lists given in the sequel. So, also, with specimens kindly communicated by the Rev. O. Fisher, F.G.S., and W. Cunnington, Esq., F.G.S., as well as my own large collection.

§ III. The Ostracoda of Wealden and reputed Wealden Strata.

Fitton, Sowerby, and Mantell.—In treating of the Purbeck Ostracoda it is obviously necessary to have a preliminary notice of the Wealden species so far as they have been described; for some of the forms recur in this upper formation, and most of the series have some mutual relationships. *Cypridea valdensis* (Fitton), *C. Austeni*, Jones, *C. tuberculata* (Sow.), and *C. spinigera* (Sow.), have been referred to above, being noticed in Fitton's memoir.

In 1844 ('Medals of Creation,' vol. ii. p. 545, lign. 119, fig. 2)

* Probably No. 389, further on, at p. 325, is such a specimen, definitely characterized by *C. bononiensis*, *C. ansata*, and *C. purbeckensis*.

Dr. G. A. Mantell separated, as "*Cypris Fittoni*," a characteristic Wealden species, some of the figures of "*C. tuberculata*" in Fitton's memoir (1836).

Römer and Dunker.—The so-called "Wealden" beds of North Germany yield several interesting species, some of which are found in England also.

In 1839 Fr. A. Römer ('Verstein. norddeutsch. Oolithengebirges') figured and described (p. 52) from the "Wealden" beds of North Germany—

1. *Cypris valdensis*, Fitton, pl. 20. fig. 20, *a*, *b*. Badly drawn, and with strong beak, although the reference is made to fig. 1, pl. 21, Trans. Geol. Soc. ser. 2, vol. iv.
2. —— *oblonga*, Römer, fig. 21. Figured differently by Dunker afterwards.
3. —— *striatopunctata*, Römer, fig. 22, *a*, *b*. Figured by Dunker more distinctly afterwards.
4. —— *tuberculata*, Fitton, fig. 23. Differing, however, somewhat in shape.
5. —— *granulosa*, Fitton, fig. 24. Figured differently by Dunker subsequently.

The figures are poor, and the descriptions scanty; but the forms can mostly be recognized with the help of Dr. W. Dunker's 'Monographie nordd. Wealdenbildung,' 1846. Herein he gives—

1. *Cypris valdensis*, Sow., p. 59, pl. 13. fig. 29, *a*, *b*. Copied apparently from Sowerby's original figure.
2. —— *lævigata*, Dunker, p. 59, pl. 13. fig. 25.
3. —— *oblonga*, Römer, p. 60, pl. 13. figs. 24 & 26, *a*, *b*. Figured here with a *beak*.
4. —— *striatopunctata*, Römer, p. 60, pl. 13. fig. 32.
5. —— *granulosa*, Sow., p. 60, pl. 13. fig. 31. Differing from *C. granulosa*, Sow., in Fitton's memoir, pl. 21. fig. 4.
6. —— *tuberculata* (?), Sow., p. 60, pl. 13. fig. 30, *a*, *b*. Differing from *C. tuberculata*, Sow., Fitton's memoir, pl. 21. fig. 2.
7. —— *rostrata*, Dunker, p. 61, pl. 13. fig. 27.
8. —— *pinnæformis*, Dunker, p. 61, fig. 13. fig. 28.

These are all figured as belonging to the genus *Cypridea*, having the antero-ventral notch and beak.

Of the several Ostracoda described by F. A. Römer (1839) and W. Dunker (1846), from the Purbeck-Wealden formation of North Germany (see above, and Geol. Mag. dec. 2, vol. v. 1878, pp. 104–106), Dr. C. Struckmann* refers *C. valdensis*, *C. oblonga*, and *C. granulosa* to the Purbeck division. These determinations, however, are probably open to revision.

The late Dr. Dunker regarded the Wealden of Hanover, and that of North Germany in general, as the equivalent of the English Purbeck. (In letter†.)

* 'Die Wealden-Bildungen der Umgegend von Hannover,' 1880, p. 56.

† My old friend, the late Dr. W. Dunker, of Marburg, wrote the following

Unfortunately there is much difficulty in correlating several of the above-mentioned species. In the first place, Römer gives the *beak* to one only, and Dunker figures all as being *beaked* more or less distinctly; secondly, the outlines given by the two authors disagree in nearly every case.

In the British Museum are some specimens, from Obernkirchen and the Deister; and a careful examination of them gives me the following species (associated with *Estheria elliptica*, Dunker):—

1. *Cypridea punctata* (Forbes), as figured in the Appendix of my Monogr. Foss. Estheriæ, pl. 5. figs. 26–30. I presume that Römer's fig. 20 and Dunker's figs. 27 & 28 may have been drawn from variously modified (and partially imbedded?) individuals of this species.
2. —— *Dunkeri*, n. sp. Presumably Römer's fig. 24, and certainly Dunker's fig. 31, represent a good species, which is not Sowerby's "*granulosa*," and therefore has been renamed in the sequel (p. 339).
3. *Cyprione Bristovii*, gen. et sp. nov., and } These two may pos-
4. *Darwinula** *leguminella* (Forbes). } sibly have been included under the "*Cypris oblonga*" of Römer and Dunker; but Römer's fig. 21 and description fall short of the reality of the first, and do not illustrate the second; and Dunker's fig. 26, though nearly like the first in outline, is markedly *beaked*, and therefore diverges, either really or by misadventure, from it and still more from the second form mentioned, which, however, is very abundant, and would readily furnish material for Dunker's fig. 24—a little Cypridiferous slab, of natural size.
5. *Cypridea granulosa* (Sow.), =*fasciculata* (Forbes), also occurs in these Hanoverian shales at Münden †, though not mentioned or figured by Römer and Dunker. This, we shall see, is a true Purbeckian species in England.

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note, a very short time before his death, in reply to some inquiries I had made:—

"The *Cypris striatopunctata*, Ed. Forbes, is altogether different from *C. striatopunctata*, Römer: see Dunker's 'Monographie' &c., where the latter is sufficiently well figured. Unfortunately I cannot send you a specimen, as the originals were borrowed by me and have long ago been returned. Your new species from the English Purbeck [judging from figures supplied] has nothing in common with the *C. striatopunctata* of Römer. In my opinion the Wealden of Hanover, and of North Germany in general, is equivalent to the Purbeck of England."

Communicated to me by Dr. Brockmeier, at the request of Madame Dunker, March 18, 1885.

* The generic name "*Darwinella*" was given by Brady and Robertson to a very interesting Ostracod to which this Purbeck-Wealden form is distinctly related. The same name, however, has been used already for a Sponge by Fritz Müller; and "*Darwinula*" has been suggested by a friend, and approved of by G. S. Brady, as a substitute. See further on, p. 346.

† Perhaps these belong to the "Münder-Mergel," described by Struckmann as transitional between the Portland and Purbeck formations. See Geol. Mag. dec. 2, vol. viii. 1881, p. 479.

Shotover and Netherfield Specimens.—In 1878 (Geol. Mag. dec. 2, vol. v. pp. 103–109, pl. 3. figs. 3–10) I described and figured some Ostracoda from the Ironstone of Shotover Hill, near Oxford. These include both Wealden and Purbeck species. Some of the specific determinations require revision. *Candona Phillipsiana* (p. 108), fig. 3, seems to be a good species; but I failed in my endeavour to fix the *Cyprideæ* figured as 5, 6, and 7; for fig. 6 is in all essentials equivalent to the Purbeck species, *C. granulosa* (Sow., in Fitton, which I now find has the *beak and notch*), being granulated at the ends and not in middle, and it was badly grouped with the spinose valves (with *sharp* tubercles), figs. 5 and 7; nor was the collocation of fig. 4 (a coarsely tuberculate form) with these correct. They are all called *verrucosa* (pp. 108, 109), but the last may well be the type of the species, the intensity of its warty ornament having caused it to be regarded as the strongest, or var. *crassa* (p. 108); whilst the spiny valves are not truly verrucose or warty, and the slightly verrucose fig. 6 must go to *C. granulosa* (Sow.), since the latter is found to be really a *Cypridea*. I now find specimens like figs. 5 and 7 in the Wealden shales of Sussex, and propose to call them *C. aculeata*.

Fig. 8 and fig. 1 of Fitton's pl. 21 (which latter is not "*valdensis*," though called so by him and Sowerby) were treated by me, in the paper referred to, as *Cypridea Austeni* (pp. 109, 110, 277). Figs. 9 and 10 were named by me *C. bispinosa*; and this seems to be a permanent form, having representatives in the Sussex Weald. Fig. 11 is an outline of the common *C. valdensis*, like that of Kent and Sussex.

Of the other Ostracoda in pl. 3, Geol. Mag. 1878, figs. 12–16 were from the "Subwealden Boring" at Netherfield, near Battle, in Sussex. Fig. 12 is probably a *Darwinula*, near to *D. leguminella* (Forbes); figs. 13–15 are *Cypridea punctata* (Forbes), not "*valdensis*," p. 110; and fig. 16 is *C. granulosa* (Römer and Dunker), p. 110, but, for convenience of nomenclature, now named *Dunkeri*: all from the Upper Purbeck.

The Shotover species will therefore stand thus:—

Fig. 3. *Candona Phillipsiana*, Jones.
4. *Cypridea verrucosa*, Jones.
5, 7. —— *aculeata*, Jones.
6. —— *granulosa* (Sow.). A characteristic Mid-Purbeck species.
8. —— *Austeni*, Jones.
9, 10. —— *bispinosa*, Jones.
11. —— *valdensis* (Fitton).

Those from the boring at Netherfield thus:—

Fig. 12. *Darwinula*?
13, 14, 15. *Cypridea punctata* (Forbes).
16. *C. Dunkeri*, Jones.

In Mr. Topley's 'Geology of the Weald' (Geol. Surv. Mem. 1875)

there are several references to the occurrence of Cypridæ in the Purbeck beds near Poundsford, Mountfield, and elsewhere in Sussex (pp. 31, 41, 408, &c.); but the specific determinations are doubtful. The specimens were noted on the spot by Mr. Etheridge, but have been since mislaid.

Synonyms of CYPRIDEA AUSTENI *, *Jones*, 1878.

Cypris valdensis, Fitton and Sow. (not Sow., Min. Conch. tab. 485), Trans. Geol. Soc. ser. 2, vol. iv. 1836, p. 177, pl. 4. fig. 1.

Cypris granulosus (part), Mantell (not Sow.), Wonders of Geology, 1838, vol. i. p. 344, tab. 46. fig. 7; *C. granulosa*, 6th edit. 1848, vol. i. p. 405, lign. 98, fig. 1; 7th edit. 1857, p. 419, lign. 104, fig. 3; Medals of Creation, 1844, vol. ii. p. 545, lign. 119, figs. 1, 1 *a*; 2nd edit. 1854, vol. ii. p. 527, lign. 174, figs. 1, 1*a*.

Cypris valdensis, Lyell (not Sowerby, Min. Conch.), Elements of Geology, 1838, p. 348, fig. 185; 2nd edit. 1841, vol. i. p. 417, fig. 201; 3rd edit. (as 'Manual of Elem. Geol.'), 1851, p. 228, fig. 233; 4th edit. 1852, p. 228, fig. 233; 5th edit. 1855, p. 263, fig. 306.

Cypridea Austeni, Jones, Geol. Mag. dec. 2, vol. v. 1878, pp. 109. 110, 227, pl. 3. fig. 8.

Dr. Fitton's wording at p. 177 of his memoir would necessitate the adoption of the name "*valdensis*" for this form, to the figure of which (his fig. 1, pl. 21) he there refers, were it not that he alludes to Sowerby's description of the real *valdensis* as *Cypris faba* (a name by which it was at first known), and especially refers to Sowerby's figure in the 'Min. Conch.' tab. 485, as well as to the "profuse abundance" of the species in the Wealden Beds.

§ IV. List of Specimens with well-determined Localities and Horizons.

I. *Ostracoda from the Upper-Purbeck Beds.*

DORSET.

§ 1. *Durlston Bay* †.

Nos. of the specimens in T. R. J.'s Collection.	Locality.	Collector or Museum.	Species ‡.
117 &293.	"Near Peverel Point," ‖ Swanage "W. of Flagstaff; below other marl"		*punctata* and var. *posticalis*.

* Named after my friend the late Mr. R. A. C. Godwin-Austen, of Shalford, in whose company I found the specimen at Peasemarsh, and who directed me to the shale-heap of Upper-Weald Clay, thrown out in digging a reservoir at the brewery there.

† A general account of the Purbecks of Durlston Bay is given by Mr. Hudleston and others in the Proc. Geol. Assoc. vol. vii. pp. 377 and 386–390.

‡ The generic names are omitted for convenience.

‖ See also Catal. Rock-specimens Mus. Pract. Geol. 1862, pp. 143, 144, "compact freshwater limestone in thin bands, in Upper Cypris-shales of the Upper-Purbeck Beds." Note also that "*C. punctata*" is quoted from the Marble-rag beds, Upper Purbeck. at p. 143.

List of Specimens &c. (*continued*).

Nos. of the specimens in T. R. J.'s Collection.	Locality.	Collector or Museum.	Species.
34 & 48.	"Durlston Bay.	J. Morris," April 1, 1883.	
34 A.	"Durlestone."	Collected by Prof. E. Renevier when he was in England in 1854–5.	*punctata.*
34 B & 34 C.	Peverel Point	J. C. Mansel-Pleydell, F.G.S.	*punctata.*
34 D.	"Durlestone. Brodie, Jun."	British Museum.	*punctata.*
405.	Durlston Bay. "Between Burstone and Marble-beds." Impure laminated limestone, composed of *C. punctata* and broken *Cyclas*.	J. C. Mansel-Pleydell, 1884.	*punctata.*
397 A & B.	Durlston Bay. "A. Cypris-shale." Rotten calcareous shale, composed chiefly of *C. punctata* and a small form.	J. C. Mansel-Pleydell, 1884.	*punctata.* *ventrosa.* *leguminella.* *Dunkeri.*
40.	"Durlestone Bay."	....	*ventrosa.* *Bristovii.*
40 A & 40 AA.	Durlston Bay. Cypris-beds.	Rev. O. Fisher, F.G.S. British Museum "59254;" and another specimen, "W. R. Brodie, Brit. Mus."	*punctata.* *ventrosa.* *Bristovii.*
133.	Durlston. "No. 4 bed of Austen's list." "Cypris-shales."		*punctata.*
367.	"Peveril Point. Bed no. 84 of Mr. Bristow's list in Damon's new edition of the 'Geology of Weymouth,' 1884, p. 201. Dark-grey shales, with band of crystalline limestone."	Horace B. Woodward *, F.G.S., 1884.	*ventrosa.*
379.	"Durlstone Bay, bed no. 84. Dark-green shales."	H. B. W. 1884.	*punctata.*
	Durlston Bay. "Crocodile Bed."	W. R. Brodie. Brit. Mus.	*punctata.*

§ 2. *Mewps Bay.*

27.	"Meups Bay" †. "Cypris-shales."	....	*punctata.* *tuberculata.* *Bristovii* (small).
	"Mupes Bay." Thin Cypridiferous limestone. Named "*Cypridea tuberculata*" and "*valdensis* in the Catal. Foss. M. P. G." 1865, p. 254.	Museum Practical Geology, $X_B \frac{5}{3}$.	*punctata* and var. *gibbosa.* *Dunkeri.*
377.	"Mewps Bay, Upper Cypris-shales." Thin, blue-hearted limestone, composed of Cyprids ‡.	Horace B. Woodward, July 1884.	*punctata.* *leguminella.*
378.	"Mewps Bay. Limestone bands in Upper Cypris-shales."	H. B. W. July 1884.	*punctata.* *leguminella.*

* Of all the specimens presented to me by Mr. Horace B. Woodward, there are good representatives in the Museum of Practical Geology.

† "Mewps Bay" in Catal. Rock-specimens Mus. Pract. Geol. 1862, p. 144.

‡ So abundant are the Cypridæ in the Purbeck formation that many strata are wholly composed of these Microzoa. Some such beds furnish good building-stone. The Rev. O. Fisher informs me that the spire of All-Saints' Church in Dorchester was built of the "Cypris-freestone," "No. 143" in his list of the Swanage strata in the Trans. Cambridge Phil. Soc., and topped with a conical block of stone from the bed no. 134, consisting of cockle shells.

List of Specimens &c. (*continued*).

Nos. of the specimens in T. R. J.'s Collection.	Locality.	Collector or Museum.	Species.
	§ 3. *Bacon Hole.*		
	Bacon Hole. Specimen $XB\frac{5}{2}$ (Catal. Foss. M. P. G. 1865, p. 254). Bacon Hole. Thin Cypridiferous limestone.	British Museum.	*punctata.* *tuberculata.* *leguminella.*
	§ 4. *Ridgway.*		
	Ridgway. With *Paludina.*	M. P. G. $\frac{32}{52}$	*punctata.*

Cypridea punctata is notably the most abundant species in the Upper-Purbeck Series.

II. *Ostracoda from the Middle-Purbeck Beds.*

I.—Dorset.

§ 1. *Durlston Bay.*

39 & 118.	Near Swanage. Specimens chipped off a large block of Purbeck Limestone (bearing vermiform markings and two large pachydactylous trifid footmarks), which formerly stood in the Hall of the Geological Society's Apartments in Somerset House, before the removal to Burlington House. Another such block is in Corfe-Castle Museum.		*fasciculata**.

"The bed with trifid marks comes in the 'Corbula-beds' of the Middle Purbeck at Durlston Bay [nos. 24–29 of J. H. Austen's section, 1852]. It is the 'Toad's-eye Limestone' marked 'No. 68' in the section published in the new edition of Mr. Damon's book, 1884, p. 203. This 'Toad's-eye Limestone' is a variable bed, splitting up into three or four layers; but sometimes these are not distinct, and it then simply has 'rotten' veins of indurated marl."—H. B. Woodward; Letter, 26th October, 1884.

74.	"Durlston Bay. Top of the Cinder-bed." †		*fasciculata.*
31.	"Lower beds of Middle Purbeck. Cypris-limestone."...		*fasciculata.*
44.	Hard, blue-hearted, thin limestone or compact Cypridiferous shell-grit. "Below the Reptile Bed. ‡	J. Morris, Nov. 21, 1873."	*ventrosa*, and var. *globosa.* *Bristovii.*
56, 57, 58.	Shale. Cypridiferal shale, largely composed of broken and perfect valves. "Lower bed of Middle Purbeck." "Below Beckles's bed" (no. 93 of Austen's list, p. 13, called a "dirt-bed," but really a lake-bottom).		*punctata.* *Bristovii.*
	Durlston Bay. Thin crystalline limestone, composed of Cyprids, and showing them freely on the weathered flaking of the surface.	M. P. G., $XB\frac{4}{2}$.	*fasciculata.*
	Durlston Bay.	M. P. G., $XB\frac{4}{4}$.	*punctata.*

* This name is used here for convenience, it being well known and indicating the more pronounced and common modification of *Cypridea granulosa* (Sow.).

† See 'Catal. Rock-specimens, M. P. G.' 1862, p. 142.

‡ There are several reptiliferous beds; if the bed worked by Mr. S. H. Beckles be intended, it is no. 93 of the Rev. J. H. Austen's list, 1852, at the base of the Middle Purbecks.

List of Specimens &c. (*continued*).

Nos. of the specimens in T. R. J.'s Collection.	Locality.	Collector or Museum.	Species.
	Durlston Bay. Thin limestones.	M. P. G., XB$\frac{4}{3}$.	*punctata.* *ventrosa.* *leguminella.*
388*.	Durlston Bay. Very thin Cypridiferous limestone.	M. P. G., XB$\frac{4}{2}$.	*punctata.* *tuberculata.* *leguminella.*
	Durlston Bay.	M. P. G., XB$\frac{4}{4}$.	*punctata.*
	Durlston Bay.	M. P. G., XB$\frac{4}{6}$.	*fasciculata.* *punctata.* *Forbesii.*
	"Durlston; between H and I." With *Melanopsis.*	M. P. G., $\frac{32}{36}$.	*fasciculata* (very large).
369.	"Durleston Bay. Bed no. 48*; 'lias rag.'"	H. B. W., 1884.	*punctata.*
408 & 409.	"Durleston Bay, Swanage, 'Turtle-beds,' between Freestone Quarry and Down's Vein," with *Cyrena.* (Austen's nos. 63–67, about.)	J. C. Mansel-Pleydell, 1884.	*paucigranulata.*
74.	Durlston Bay. "From the top of the Cinder-Bed."	Rev. O. Fisher, January 1883.	*fasciculata.*
406 & 407.	"Durleston Bay, Swanage. Above Cinder-bed."	J. C. Mansel-Pleydell, 1884.	*paucigranulata,* fine and large specimens.
396, 399, 401, 402, 403.	"Durleston Bay. Under Cinder-bed." With *Ostrea.* (Lower part of Austen's no 71 ?)	J. C. Mansel-Pleydell, 1884.	*paucigranulata.*
	"Durleston Bay. Below Cinder-bed." With *Cyrena* and *Melanopsis* ? (Austen's no. 72.)	J. C. Mansel-Pleydell, 1884.	*paucigranulata.*
	"Button Bed. Purbeck I. 8809. Greenough."	Geol. Soc.	*fasciculata.*
	"Tombstone Bed. Swanwick. 8743. Greenough. In clayey parting." This is no. 45 of Bristow's List (in Damon), 1884; and nos. 69 and 70 of Austen's List, 1852.	Geol. Soc.	*punctata* ?
	"Tillywhim Hill. Fitton, 929." Limestone.	Geol. Soc.	*fasciculata.*

§ 2. *Mewps Bay.*

	Mewps Bay. With *Valvata.*	M. P. G. $\frac{32}{24}$.	*fasciculata.*
61.	Mewps Bay.	And M. P. G. XB$\frac{4}{5}$,	*posticalis.* *Dunkeri.* *leguminella.* *Forbesii.*

§ 3. *Worbarrow Bay.*

370.	"Worbarrow Bay. Marly limestone. *Cypris* abundant. Cherty freshwater."	H. B. W., July 1884.	*fasciculata.*

§ 4. *Ridgway.*

	Ridgway.	M. P. G. XB$\frac{4}{5}$.	*posticalis.* *Dunkeri.* *leguminella* ? *Forbesii.*
381.	"Ridgway Hill. Coarse marly limestone with yellow stains."	H. B. Woodward, July 1884.	*fasciculata.*

* Mr. Bristow's list in the new edition of Damon's 'Weymouth,' &c.

List of Specimens &c. (*continued*).

Nos. of the specimens in T. R. J.'s Collection.	Locality.	Collector or Museum.	Species.
123 A.	"Ridgway. Chert and its dirt-bed." 1855. With *Chara*, fishbone, &c. "Chert-bed, Ridgway. O. Fisher." With *Chara*, and *Planorbis*?	Geol. Soc.	*valdensis* †. *punctata*. *Forbesii*. *leguminella*,

II. Wilts.—*Vale of Wardour.*

38 & 45.	Teffont.	W. Cunnington, F.G.S., Sept. 1870.	*fasciculata*.
83, 84, 85.	Teffont.	Rev. O. Fisher, January 1883.	*fasciculata*.
	Teffont. The Rev. O. Fisher, in the Rev. P. B. Brodie's paper, Quart. Journ. Geol. Soc. vol. x. p. 476, mentions		*fasciculata*.
	Vale of Wardour. With *Cyrena*.	M. P. G. $\frac{31}{40}$.	*fasciculata*.
387*.	"Dallard, Wilts. Fitton." Limestone, made up of Cypridæ.	Geol. Soc.	*punctata*.
194.	"Between Hand Cross and Chicksgrove." See Fitton's 'Memoir on the Strata below the Chalk,' &c., 1837, pp. 251, 260 Cypridæ, with some casts of *Cyrena*, making up the rock. Casts of *Cyrenæ* full of Cypridæ. The rock a mass of Cypridæ.		*fasciculata*.
197.	Ladydown. See Fitton's 'Memoir,' &c., pp. 262, 272.		*fasciculata*.
	"Lady Down. Miss Benett. 9674."	Geol. Soc.	*fasciculata*.
	"Lady Down in Tisbury. Miss Benett." With Fish-remains (*Sauropsis*).	Geol. Soc.	*fasciculata*.
	"Between Dallard and St. Catherine's Ford. Fitton."	Geol. Soc.	*fasciculata*.

Cypridea granulosa (*fasciculata*) is particularly characteristic of this division of the series, and *Metacypris Forbesii* is also peculiar to it.

III. *Ostracoda from the Lower-Purbeck Beds*.

I. Dorset.

§ 1. *Portland.*

389.	"Purbeck stone, Portland." Fitton. Marked as containing "*C. faba*" (=*C. valdensis*). A white limestone.	Geol. Soc.	*bononiensis*. *ansata*. *purbeckensis*.

§ 2. *Durlston Bay.*

366 & 368.	"Durlston Bay, Isle of Purbeck. Bed No. 9 of Lower Purbeck ‡. Soft grey Cypris-shales."	Horace B. Woodward, July 1884.	*purbeckensis* ‖.

† This is the only instance in which I have found *Cypridea valdensis* in the Purbeck beds. Some doubtful specimens, however, may be mentioned as occurring in black shales from a pit in Archer Wood, near Battle, Sussex, and in ironstone at Poundsford.

‡ Mr. Bristow's list in Damon's new edition.

‖ *Cypris purbeckensis*, M. P. G. XB$\frac{4}{7}$, is entered in the Catal, Fossils M. P. G. 1865, p. 254, as belonging to the "Middle Purbeck" (of Durlston Bay?), together with *Serpulites* and *Archæoniscus*; but this, I think, must be a mistake, for this species and the other fossils here mentioned, for by far the most part, characteristically belong to the Lower Purbeck. It is referred to as "17 in O."

List of Specimens &c. (*continued*).

Nos. of the specimens in T. R. J.'s Collection.	Locality.	Collector or Museum.	Species.
§ 3. *Worbarrow Bay.*			
371.	"Worbarrow Bay. Hard slaty limestone with occasional partings of sandy shale. Hard Cockle-beds."	H. B. W. July 1884.	*purbeckensis.*
375.	"Worbarrow Bay. Brown Cypris-freestone."	H. B. W. July 1884.	*purbeckensis.*
§ 4. *Lulworth.*			
273.	Lulworth.		*purbeckensis.* *bononiensis.*

In the 'Catalogue of Rock-specimens, Mus. Pract. Geol.' 1862, p. 141, a piece of "grey slaty limestone" of the Lower-Purbeck Series, "with pale marly clay," in the "Soft Cockle-beds," and containing pseudomorphous casts of salt-crystals, is described as having its "upper and under surfaces. . . ., as well as the casts of crystals . . . . thickly covered with *Cypris leguminella.*" Though these little bodies at first sight closely resemble *Darwinula leguminella*, they are really minute, subcylindrical, oolitic concretions * composing the rock. They stand out whitish on the surfaces, more distinctly than elsewhere, on account of weathering; in the limestone they have a brownish tint, and under the microscope the cementing matrix is calcareous. Mr. Cunnington has shown me a specimen from Chicksgrove (not far from Teffont), which has these oolitic grains interstratified with a dense argillaceous limestone.

In a grey marly limestone from Teffont, with chert, and containing fish-remains (in the Rev. W. R. Andrew's collections), I have seen a thin layer of similar oolitic granules, some botelloid, but most of them round and ovoid.

§ 5. *Ringstead Bay.*			
376.	Ringstead Bay. From H. B. W. July 1884. This is a mass of small roundish granules and Cypridæ, coated more or less with calc-sinter, including also small tubes (*Serpulæ* ?). This is comparable with a similar Purbeckian bed near Boulogne, see 'Proceed. Geol. Assoc.' vol. viii. p. 58, and 'Bullet. Soc. Géol. France,' ser. 3, vol. viii. p. 616.		*purbeckensis.*
§ 6. *Ridgway.*			
67.	Ridgway Hill. From the Rev. O. Fisher †, Jan. 1883.		*purbeckensis.*
372.	"Ridgway Hill, Upway. Middle rock. Soft Cypris-limestone."	H. B. W. July 1884.	*purbeckensis.*
373.	"Ridgway Hill, Upway."	H. B. W. July 1884.	*purbeckensis.*
380.	"Ridgway Hill, Upway. Dense Cypris-limestone."	H. B. W. July, 1884.	*purbeckensis.*

* This is a different oolite from that of the specimen no. 384 from Ridgway, p. 327.

† See the Rev. O. Fisher's "Memoir on the Purbeck Strata," &c. Trans. Cambr. Phil. Soc. vol. ix. 1855; Nos. 1 and 2 of the Ridgway List. Given also in Damon's 'Geology of Weymouth,' &c. 1860, p. 111.

List of Specimens &c. (*continued*).

Nos. of the specimens in T. R. J.'s Collection.	Locality. Collector or Museum.	Species.
384.	"Upway, Dorset." Marly limestone with shell-grit and coarse oolite. H. B. W. 1885.	*purbeckensis.*

II. Wiltshire.

§ 1. *Vale of Wardour.*

	Teffont. In the Quart. Journ. Geol. Soc. vol. x. p. 477, the Rev. O. Fisher * refers to the local species from the Lower Purbeck of Teffont.	*purbeckensis.*
	Teffont. Specimen in Mr. W. Cunnington's Collection, named by Prof. E. Forbes.†	*purbeckensis.*
230.	Vale of Wardour. Silicified wood with very fine specimens of	*purbeckensis.*
75–82.	Vale of Wardour.	*purbeckensis.* *bononiensis.* *ansata.*
365.	Lowest Purbeck Bed ‡, lying on the Portland Limestone at Oakley (Wockley) Quarry near Tisbury, in the Vale of Wardour. A block of this is preserved in the Museum of Practical Geology, Jermyn Street. It has been described by H. W. Bristow, in the 'Catalogue of the Rock-specimens in the M. P. G.' 3rd edit. 1862, p. 139; and it has been referred to by Prof. J. F. Blake in the Quart. Journ. Geol. Soc. vol. xxxvi. 1880, pp. 190, 200; by Sir A. C. Ramsay, *ibid.* p. 236, and by W. H. Hudleston, in the Proc. Geol. Assoc. vol. vii. 1881, p. 174.	*bononiensis.* *ansata.*

* I have also received from him (Jan. 1883) *C. purbeckensis* collected at Teffont by the Rev. W. R. Andrews.

† Extract from a paper on 'The Geology of the Vale of Wardour,' by Mr. W. Cunnington, F.G.S., read at the Blackmore Museum, Salisbury. (In a letter from Mr. Cunnington, February 1885.) "According to Prof. E. Forbes *Cypris tuberculata* is found only in the Upper Purbecks, *Cypris fasciculata* in the Middle, and *Cypris purbeckensis* in the Lower......It appears that the Upper Purbecks are altogether wanting in the Vale of Wardour..........

"In the year 1851 I had the pleasure of accompanying Prof. E. Forbes and other geological friends in a tour through the Vale of Wardour. Passing down a lane between Teffont and Tisbury, I broke off from the rock at the side of the road, a small piece of stone full of Cyprides; and, showing it to him, he said, 'This is *Cypris fasciculata*; within a few yards lower down you ought to find *Cypris purbeckensis*;' and, as he predicted, within the space mentioned, I found the very species. The specimens are now on the table......As this was Mr. Forbes's first visit to the spot, the incident affords a striking proof of his geological knowledge."

‡ Possibly the estuarine Portlandian (succeeding the marine Portlandian), or the "precursor of the Purbecks," Hudleston, Proc. Geol. Assoc. *loc. cit.* See also Prof. Judd's remarks on the passage from the Portland into the Purbeck, Quart. Journ. Geol. Soc. vol. xxviii. 1871, p. 223, and Mr. Godwin-Austen's Section at Swindon, Quart. Journ. Geol. Soc. vol. vi. 1850, pp. 464–467, also Prof. Blake's, *ibid.* vol. xxxvi.

The geology of the Vale of Wardour has been treated of by Dr. W. Fitton in his memoir "On the Strata below the Chalk," &c. Trans. Geol. Soc. ser. 2, vol. iv. 1836, and the Purbeck beds of the district are especially mentioned, thus:—Dallard's Farm, pp. 250, 260; Dashlet, pp. 250, 260; Chicksgrove, pp. 251, 260; Wockley, p. 252; Teffont, pp. 259, 260; Lady Down, pp. 262, 272. See also the Rev. P. B. Brodie's papers, Proc. Geol. Soc. vol. iii. 1839, 1842, pp. 134, 780; Quart. Journ. Geol. Soc. vol. x. 1854, pp. 475, 482; and especially the Rev. W. R. Andrews's memoir, Quart. Journ. Geol. Soc. vol. xxxvii. 1881, pp. 248–253, and Mr. W. H. Hudleston's in Proc. Geol. Assoc. vol. vii. 1881, pp. 161, &c.

List of Specimens &c. (*continued*).

Nos. of the specimens in T. R. J.'s Collection.	Locality. Collector or Museum.	Species.
	"Chicksgrove or Wockley. Bottom of the Cap." With Fish-remains. Geol. Soc.	*purbeckensis.* *ansata.*
	§ 2. *Swindon.*	
364.	Swindon. Collected by the Rev. Prof. J. F. Blake *.	*transiens.* *retirugata.*
	III. Buckinghamshire.	
	§ 1. *Whitchurch*, &c.	
363.	South Oving, Bucks. J. F. Blake (Quart. Journ. Geol. Soc. xxxvi. p. 215).	*purbeckensis.* *bononiensis.* *ansata.*
234.	"Quainton. Western pit. Pendle." † Fitton, May 18, 1834, vol. 15, p. 122" (notebook ?). See Fitton's memoir, p. 290.	*bononiensis.* *ansata.*
235.	Quainton. Pendle, with "*Mytilus, Cyclas parva*, and *Cypris*." Fitton.	*ansata.*
232 & 228.	"Whitchurch." "Pendle." Fitton. "May, 1834, vol. 15."	*purbeckensis.* *bononiensis.* *ansata.*
226.	"Whitchurch." "224." Fitton's memoir, p. 289.	*ansata.*
227.	Whitchurch? "1527–1053." "*C. faba.*" Fitton.	*purbeckensis.*
	"Whitchurch. 1520. Fitton." Shell-grit with Cyprids called *C. faba.* Geol. Soc.	*bononiensis.* *purbeckensis.* *ansata.*
	"Whitchurch. Fitton. 1522." Geol. Soc.	*purbeckensis.* *bononiensis.* *ansata.*
	"Pendle. Whitchurch. Fitton." Geol. Soc.	*purbeckensis.* *ansata.*
	"Pendle. Whitchurch." With vertebræ of fish, an oblong bivalve, and an impression of a leaf (?). Geol. Soc.	*ansata.*
	Stewkley. M. P. G. XB$\frac{2}{4}$. Catal. Foss. 1865, p. 253. See also Fitton's memoir, p. 291.	*purbeckensis.* *bononiensis.* *ansata.*

In an interesting section of Purbeck and Portland strata ‡ at the farm called the Warren, 1¼ mile south of Stewkley Church, which I had the pleasure of examining with Prof. A. H. Green in 1862, I noticed a Cypridiferous shale above the true Portland beds, and below a bed with *Trigonia.* Unfortunately I have mislaid the specimens then collected.

§ 2. *Hartwell, near Aylesbury* ‖. *The Pit near the Bugle Inn.*

172, 176, 178, 179, 184, 189, 191A.	Soft limestones, marls, and clay.	*purbeckensis.*
179, 180, 191A.	Soft limestone, marls, and clays	*bononiensis.*
179, 189, 191A.	Soft limestones, marls, and clays	*ansata.*
173.	Dense green clay.	*rugulata.*
180.	Crumbly clay.	*retirugata.*

* See Quart. Journ. Geol. Soc. vol. xxxvi. pp. 203–207. See also C. Moore's remarks on the section and fossils of Purbeck beds at Swindon, Proc. Geol. Assoc. vol. iv. 1879, p. 543, &c.; and further on, p. 330.

† The "pendle," a Purbeckian bed, found in both Bucks and Wilts, consists of a white, grey, or creamy limestone, somewhat argillaceous, generally fissile above and solid below, and contains at Whitchurch rounded whitish particles. It has been found to contain, at places, "*Cyprides*," *Modiolæ, Paludina, Cyclas parva, Planorbis* ?, and *Potamides carinatus.*

‡ See also Fitton's Memoir, p. 291.

‖ The particulars of the sections of this and the following quarries having been partly mislaid, their more perfect exposition is delayed for some future opportunity.

List of Specimens &c. (*continued*).

Nos. of the specimens in T. R. J.'s Collection.	Locality.	Collector or Museum.	Species.
§ 3. *Hartwell.—Barnard's Pit* (or "*pit at Barnett's Close*") *.			
162, 166.	Shaly beds.		*purbeckensis.*
162, 166,	Shaly beds.		*ansata.*
166.	Shaly beds.		*retirugata* (var. *textilis*, Pl. ix. f. 24).

§ 4. *Hartwell.—Bishopstone Pit* (on the road between Bishopstone and Stone). Fitton's Memoir, pp. 287, 297 ("Horton's pits" and "Dr. Lee's pit," at p. 297). This is the same as pit "no. 200" on the plan of the late Dr. Lee's property at Hartwell.

Nos.	Locality.	Collector or Museum.	Species.
238, 241, 245.	Blue clay, with fish-scales (*Pleuropholis*). Fitton's Memoir, p. 287. Marked "200" on Fitton's label. See also Brodie's section of this quarry (near Stone), Proc. Geol. Soc. vol. iii. 1842, p. 781.		*purbeckensis.* *bononiensis.*

§ 5. *Hartwell* (*other pits*).

Nos.	Locality.	Collector or Museum.	Species.
	Near Aylesbury; with *Mytilus.*	M. P. G. $\frac{31}{1}$.	*bononiensis.* *ansata.*
258.	Grey clay on the Pendle.		*bononiensis.* *ansata.* *rugulata* (Pl. ix. f. 20).
247, 255, 260, 261, 350?, & I. 165, British Museum.	The Pendle.		*purbeckensis?* *bononiensis.* *ansata.*
269.			*rugulata* (Pl. ix. f. 19). *ansata.*
256.			*rugulata* (Pl. ix. f. 17 & 18). *bononiensis?* *ansata?*
253.	"Last Portland bed."		*bononiensis.* *ansata.* [f.21–23). *retirugata* (Pl. ix. with an Echinoderm spine.
353, 350, 361, 355.	Soft limestones and clay (361)		*purbeckensis.* *bononiensis.* *ansata.*
360.	Soft friable limestone.		*bononiensis.* *ansata.*
354.	Grey clay		*bononiensis.* *ansata.*
357.	Friable shale. "Trigonia; next to Portland."		*bononiensis, rugulata.*

In the Lower-Purbeck series the characteristic Ostracods are:—

Cypris purbeckensis,
Candona bononiensis,
Candona ansata,

as will be seen by reference to the foregoing local lists for Wilts, Dorset, and Buckinghamshire. At Swindon, however, Prof. J. F. Blake found a "Purbeck" stratum which has yielded two new

* 'London University Magazine,' June 1856, p. 103.

species of *Cythere*, *C. transiens* and *C. retirugata*. Of these, the latter occurs in the lowest Purbeck beds in two of the stone-pits at Hartwell, near Aylesbury, namely the "Bugle pit" and "Barnard's pit." A variety, or the male form (*rugulata*), of *C. retirugata*, occurs both in the last-mentioned quarry and in similar low Purbeck (if not really *estuarine Portland*) beds in other pits near by.

The mingling of what seem to be freshwater with marine species in these lowest strata is a subject of much interest, and will require further attention and close study of the succession of strata. *C. transiens* has been found also in white, soft, Portland Stone, from Brill in Bucks.

IV. *Purbeck Beds near Mountfield and Poundsford, Sussex.*

The overlying Cypridiferous shales near Mountfield contain *Cypridea valdensis*, *Darwinula leguminella*, and *Cypridea Austeni* (?), and belong to the Wealden series; but the limestones that have been brought up from the old pits at Limekiln Wood, near by, contain Purbeck species, thus:—

63. Light-coloured limestone	*granulosa*, Sow. (=*fasciculata*, Forbes.)
25, 286, 312, 346. Solid bluish limestone, apparently composed of Cypridæ, and showing them as casts and moulds on the weathered surfaces	*punctata* ?
307. Blue shale, with a thin layer of the small botelloid oolite which is seen in Purbeck specimens from Teffont, &c.	In the shale, *Dunkeri*?
Oyster-bed. Ostracods, chiefly casts, weathered out free ...	*Cythere* ? &c.

In ironstone at Poundsford we find *Cypridea valdensis* (?), *Darwinula leguminella*, and insect-remains.

Purbeck beds from the Sub-Wealden Boring at Netherfield.

390, 411, 412. Dark grey impure limestones, at 85 feet and 96 feet depth	*punctata*, with *Chara*.

V. *The late Mr. Charles Moore's Specimens from the Purbeck Beds at Swindon, Wilts.*

In the 'Proceed. Geol. Assoc.' vol. iv. 1876, pp. 544–546, there is an account of the late Mr. Charles Moore's discovery of many fossils in the Purbeck beds in the Great Quarry at Swindon; and among the fossils mention is made of four or five species of *Cypris*.

The Rev. H. H. Winwood, F.G.S., has been so good as to look for these fossils in the Bath Museum; and from among C. Moore's Upper-Oolite collection he has sent me six little glass tubes containing Ostracodal valves. On examination, these prove to be similar to other Purbeck species. Thus:—

Tube 59. *Cypridea punctata*, ordinary; and *C. Dunkeri*, with very strong beak and notch. *C. Dunkeri* is much more numerous than the other. About 90 altogether.

Tube 60. *Cythere retirugata* and its var. *rugulata*; ordinary; about 60.

Tube 61. *Cythere retirugata* and its var. *rugulata*, ordinary; and one *Cypris purbeckensis*: 20 specimens altogether. In both 60 and 61 *rugulata* is more common than the other.

Tube 62. *Cypridea punctata*; very large. Numerous; about 80.

Tube 62*. *Candona bononiensis* and *C. ansata* (both ordinary), 15; and *Cypridea punctata* (ordinary), only one.

Tube 65. *Cypridea punctata*, ordinary; and *C. Dunkeri*, like that of tube 59, more numerous than *C. punctata*; about 250 of the two together.

Certain strata at Swindon containing "*Cyprides*" are described, *loc. cit.*, as freshwater marls and limestones, 10 feet thick, with depressions ("pipe-like veins") in them, containing material derived from the Lower Greensand. Further, they are referred to as chalky limestones, in which are one or two darkish bands of earthy, carbonaceous marls and loose grits, containing mixed marine and freshwater forms. C. Moore also remarked that "the chalky limestones or marls contain few remains of recognizable character"; but, together with several smaller *derived* fossils, he got four or five species of *Cypris* "from the black bands," or "earthy carbonaceous marls and loose grits" (the "black carbonaceous friable loam," Hudleston, *op. cit.* p. 548). The specimens in the tubes above referred to are (from both internal and collateral evidence) believed to be Mr. C. Moore's Swindon specimens.

These deposits † were referred to the Middle Purbeck, with some doubt, by Mr. C. Moore; and he suggested that Purbeck beds of older date may have been cut into, disturbed, and mixed up with them. Prof. Morris gave his opinion (p. 547) that these beds "might be the equivalents of the entire thickness" of the Purbeck series (300 feet at Durlston Bay).

Either of these suggestions will account for the occurrence of the Lower-Purbeck species:—*retirugata*, *rugulata*, *bononiensis*, *ansata*, and *purbeckensis* in company with *Dunkeri* and *punctata*. Had *fasciculata* turned up also, we should have had a fairly representative and complete group.

§ V. Conclusion.

In conclusion there are fourteen species of Ostracoda in E. Forbes's three divisions of the Purbeck series of deposits. Five of them occur only in the Lower Purbeck. Of the others, six occur in both the Middle and the Upper. Of the fourteen, five go up into the Wealden, from the Middle and Upper divisions only. See the following Table (p. 332). *Cypridea punctata* for the Upper, *C. granulosa* (*fasciculata*) for the Middle, and *Cypris purbeckensis* for the Lower Purbeck, are especially characteristic.

† At p. 548, *op. cit.*, Mr. Hudleston notes that this "black carbonaceous friable loam" becomes further on a bed of *Cerithium portlandicum* in "dark friable marly grit," and "that above this bed the regular Portland Limestone comes on again," "Purbeck" and "Portland" conditions inosculating at this spot. Prof. Blake's interpretation of the section is different.

§ VI. Tabular Conspectus of the Purbeck Ostracoda.

	Species and Varieties.	Purbeck. *England.* Lower.	Purbeck. *England.* Middle.	Purbeck. *England.* Upper.	Purbeck. ("Wealden.") *N. Germany.*	Wealden. *England.*	Remarks.
1.	Cypridea valdensis (*Fitton*)	—	*	......	?	*	Very rare in the Purbeck, abundant in the Wealden of England.
2.	—— punctata (*Forbes*)	—	*	*	*	......	Characteristically abundant in the Upper Purbeck.
2*.	—— —— var. posticalis, *nov.*	—	*	*	......	......	Strongest in the Middle Purbeck.
2**.	—— —— var. gibbosa (*Forbes*)	—	*	*	......	......	Rare.
3.	—— ventrosa, *nov.*	—	*	*	......	......	Rather rare.
3*.	—— —— var. globosa, *nov.*	—	*	......	......	......	Rare.
4.	—— tuberculata (*Sow.*)	—	*	*	*	*	Rather rare.
4*.	—— —— var. adjuncta, *nov.*	—	—	*	......	......	Rare.
5.	—— Dunkeri, *nov.*	—	*	*	*	*	Rather rare in the Purbeck, abundant in some of the Wealden beds.
6.	—— granulosa (*Sow.*), var. fasciculata (*Forbes*)	—	*	—	*	......	} Characteristic of the Middle Purbeck.
6*.	—— —— var. paucigranulata, *nov.*	—	*	......	......	......	}
7.	Cyprione Bristovii, *nov.*	—	*	*	*	*	Not uncommon.
8.	Darwinula leguminella (*Forbes*)	—	*	*	*	*	Abundant in places.
9.	Metacypris Forbesii, *nov.*	—	*	......	......	......	} Found only in the Middle Purbeck.
9*.	—— —— var. verrucosa, *nov.*	—	*	......	......	......	}
10.	Cypris purbeckensis, *Forbes*	*	......	......	......	......	Characteristic of the Lower Purbeck.
11.	Candona bononiensis, *Jones*	*	......	......	......	......	} Often abundant with *C. purbeckensis.*
12.	—— ansata, *nov.*	*	......	......	......	......	}
13.	Cythere transiens, *nov.*	*	......	......	......	......	Rare: and in the *Portland* (Brill).
14.	—— retirugata, *nov.*	*	......	......	......	......	}
14*.	—— —— var. rugulata, *nov.*	*	......	......	......	......	} Rare.
14**.	—— —— var. textilis, *nov.*	*	......	......	......	......	}

§ VII. Appendix.

1. *The Ostracoda of the Wealden Formation.*

Dorset.		
Upper Weald.	Swanage Bay (Punfield Cove)	*Cypridea valdensis* *Cythere Fittoni* } separate in some beds, together in others. *Cypridea spinigera*, only in one bed and alone.
Isle of Wight.		
Upper Weald.	Grange Chine, W. of Compton...	*Cypridea valdensis.* —— *Dunkeri.*
Upper Weald.	Compton Bay	—— *valdensis.* *Cythere Fittoni.* *Cypridea spinigera.*
(Upper?) Weald.	West of Brook Point	—— *valdensis.* *Cythere Fittoni.* *Cypridea Dunkeri.*
(Upper?) Weald.	Brixton Bay	—— *valdensis.* *Cythere Fittoni.* *Cypridea Dunkeri.*
(Upper?) Weald.	Shepherd's Chine	—— *valdensis.*
(Upper?) Weald.	Cowleaze Chine	—— *valdensis.*
Upper Weald.	Atherfield	—— *valdensis.* *Cythere Fittoni.* *Cypridea spinigera.* —— *Dunkeri.* *Darwinula leguminella.*
Upper Weald.	Sandown Bay	*Cypridea valdensis.* —— *spinigera.* —— *Dunkeri.* *Cythere Fittoni.* *Darwinula leguminella.*
Sussex.		
Weald Clay.	Pulborough (railway)	*Cypridea valdensis.* *Cythere Fittoni.*
Weald Clay?	Pallingham, W. Sussex	—— *Fittoni.*
Weald Clay.	Petworth (Sussex marble)...........	*Cypridea valdensis.*
Tunbridge-Wells Sand.	Northland shale-pit, near Chripp's farm and Cuckfield...	—— *valdensis.* —— *bispinosa.* —— *aculeata.*
Tunbridge-Wells sand or clay in it.	Between Ansty Gate and Slough Green, N.W. of Cuckfield; from a well	—— *valdensis.* —— *tuberculata.* *Darwinula leguminella.*
Grinstead Clay.	Balcombe Tunnel, South-Eastern Railway	*Cypridea valdensis.*
Shale in Tunbridge-Wells Sand.	Lindfield, N.E. of Cuckfield......	—— *valdensis.* —— *spinigera.* *Cythere Fittoni.* *Cyprione Bristovii.*
Grinstead Clay, patch of, let down and preserved by a fault, in the Railway-cutting near Brook Farm, south of East Grinstead		*Cypridea valdensis.* —— *tuberculata.* —— *bispinosa.*
Tunbridge-Wells Sand.	Balcombe Quarry; with *Tornatella Popei*	—— *valdensis.* —— *tuberculata.*
Tunbridge-Wells Sand.	Uckfield	—— *spinigera.*
Wadhurst Clay.	Railway-cutting, about 1 mile east of East-Grinstead Station	*Cypridea valdensis.*
Wadhurst Clay.	$2\frac{1}{2}$ miles W. of Bexhill	*Cyprione Bristovii.* *Cypridea tuberculata.*
Wadhurst Clay?	Bopeep, St. Leonard's	—— *valdensis.* —— *Dunkeri.* —— *tuberculata.*

Wadhurst Clay.	St. Leonard's, Hastings	*Cypridea valdensis.* —— *Dunkeri.* —— *tuberculata.*
Wadhurst Clay ?	Crowhurst Road, Hastings	—— *valdensis.* —— *Dunkeri ?*
Wadhurst Clay ?	Hollington, near Hastings	—— *valdensis.*
Wadhurst Clay ?	Silver-Hill Road, Hastings (Equisetum shales)	—— *valdensis.* *Cythere Fittoni.* *Darwinula leguminella.*
Wadhurst Clay ?	Tivoli, Hastings	*Cypridea valdensis.*
Wadhurst Clay.	Quarry near the Black Horse Inn, Telham Hill, near Hastings	—— *valdensis.* *Cythere Fittoni.* *Cypridea tuberculata ?* —— *Dunkeri.* —— *bispinosa.* *Cyprione Bristovii.*
Wadhurst Clay.	Ecclesbourne Glen, Hastings	*Cythere Fittoni.* *Cypridea tuberculata.*
Ashdown Sand.	East Cliff, Hastings (W. R. & H. Binfield)	—— *valdensis.*
Ashdown Sands ?	Mountfield (shales)	—— *valdensis.* *Darwinula leguminella.* *Cypridea Austeni ?*

Kent.

Weald Clay.	Sevenoaks Tunnel	*Cypridea valdensis.* —— *spinigera ?* —— *gyripunctata*, MS. *Cythere Fittoni.* *Darwinula leguminella.*
Weald Clay.	Near Maidstone; railroad at Great Buckland; and Wateringbury	*Cypridea valdensis.* *Cythere Fittoni.*
Weald Clay.	Great Chart, South-Eastern Railway	*Cypridea valdensis.* *Cythere Fittoni.*
Weald Clay.	"Adlington" (probably Aldington)	*Cypridea valdensis.* *Cythere Fittoni.*
Weald Clay.	Bethersden	*Cypridea valdensis.*
Weald Clay.	Hythe	—— *valdensis.* *Cythere Fittoni.* *Darwinula leguminella.*
Tunbridge-Wells Sand ?	Tunbridge	*Cyprione Bristovii.*
Tunbridge-Wells Sand ?	Tunbridge-Wells; with *Tornatella Popei*	*Cypridea valdensis.*
(Upper ?) Tunbridge-Wells Sand.	Langton Green	—— *valdensis.* *Cythere Fittoni.* *Cypridea tuberculata.* —— *bispinosa ?* *Darwinula leguminella.*

Surrey.

Weald Clay.	Peasemarsh, near Guildford	*Cypridea Austeni.*
Weald Clay.	Hazlemere (railroad)	—— *valdensis ?* *Cythere Fittoni ?*
Weald Clay.	Trout's Farm, and near Henhurst, at the foot of Leith Hill	*Cypridea valdensis.*
Weald Clay.	Dorking Tunnel	—— *valdensis.*
Weald Clay.	Earlswood Common	—— *spinigera.*

2. *Synoptical List of the Ostracoda of the Purbeck and Wealden Formations in England, showing their Stages and Recurrence. (Successively numbered, 1–20, upwards from those of the Lower Purbeck.)*

Wealden Species (11 species, 5 of which come up from the Purbeck, Upper and Middle).

14. *Cypridea valdensis* (Fitton). Very rare in Mid-Purbeck, but very abundant here.
13. —— *Dunkeri*, nov. } Recurrent from the Purbeck beds.
10. —— *tuberculata* (Sowerby). }
20. —— *spinigera* (Sow.).
19. —— *bispinosa*, Jones.
18. —— *dorsispinata*, nov. MS.
17. —— *gyripunctata*, nov. MS.
16. —— *aculeata*, nov. (part of *verrucosa*, Jones).
15. *Cythere Fittoni* (Mantell). Common.
8. *Cyprione Bristovii*, nov. } Recurrent from the Purbeck beds.
7. *Darwinula leguminella* (Forbes). }

Upper-Purbeck Species (6 species, all of which recur from the Middle Purbeck; 4 go on to the Wealden).

12. *Cypridea punctata* (Forbes). Very abundant.
12**. —— ——, var. *gibbosa* (Forbes).
12*. —— ——, var. *posticalis*, nov.
13. —— *Dunkeri*, nov.
11. —— *ventrosa*, nov.
10*. —— *tuberculata* (Sow.), var. *adjuncta*, nov.
8. *Cyprione Bristovii*, nov.
7. *Darwinula leguminella* (Forbes).

Middle-Purbeck Species (9 species, 2 of which are peculiar to this Division; but 6 recur in the Upper Purbeck, and 5 in the Wealden).

14. *Cypridea valdensis* (Fitton). Very rare in the Purbeck, but common in the Wealden beds.
13. —— *Dunkeri*, nov.
12. —— *punctata* (Forbes). ...... { More abundant in the Upper Purbeck.
12*. —— ——, var. *posticalis*, nov.
12**. —— ——, var. *gibbosa* (Forbes).
11. —— *ventrosa*, nov.
11* —— ——, var. *globosa*, nov.
10. —— *tuberculata* (Sow.).
9. —— *granulosa* (Sow.), var. *fasciculata* (Forbes). } Very abundant, and peculiar to the Mid-Purbeck.
9*. —— ——, var. *paucigranulata*, nov. }
8. *Cyprione Bristovii*, nov.
7. *Darwinula leguminella* (Forbes).

6. *Metacypris Forbesii*, nov. } Rare, and peculiar to the
6*. —— ——, var. *verrucosa*, nov. } Mid-Purbeck.

Lower-Purbeck Species (5 species, all peculiar to this Division).

5. *Cypris purbeckensis*, Forbes. Most abundant.
4. *Candona bononiensis*, Jones. } Often common with *C. purbeckensis*.
3. —— *ansata*, nov. }
2. *Cythere transiens*, nov. }
1. —— *retirugata*, nov. } Marine forms; rare.
1*. —— ——, var. *rugulata*, nov. }
1**. —— ——, var. *textilis*, nov. }

§ VIII. Description of the Species.

I. Genus Cypridea, Bosquet, 1852.

Cypris, Auctorum.

Cypridea, Bosquet, 1852, Mém. couron. Acad. Roy. Belg. vol. xxiv. P. 47 of the Memoir, "Description Entom. foss. Terrains tert. France et Belg."

Cypridea (subgenus of *Cypris*), Jones in Morris's Catal. Brit. Foss. 1854, p. 104.

Cypridea (? subgenus of *Cypris*), Jones, Monogr. Brit. Tert. Entom. 1856, pp. 9, 10.

Cypridea, Jones, Monogr. Foss. Esth. 1862, p. 106, & Appendix, p. 127.

Cypridea, Huxley & Etheridge, Catal. Coll. Fossils Mus. Pract. Geol. 1865, p. 254.

Cypridea, H. Woodward, Catal. Brit. Foss. Crustac. 1877, p. 88.

Cypridea, Jones, Geol. Mag. dec. 2, vol. v. 1878, pp. 107 &c

Carapace-valves subtriangular, obovate, or ovate-oblong; convex in the middle; broad (high) at the anterior third; narrower behind; one or both ends obliquely rounded; somewhat compressed anteriorly; notched at the antero-ventral angle, behind a small beak-like process; sometimes having only a slight indentation below and behind a thickening of the antero-ventral angle; sometimes this is traceable only by a curvature of the edge inside. Edge-view more or less narrow-ovate. End-view subovate. Surface punctate; sometimes almost smooth; often tuberculate; tubercles small or large, variously disposed. The hinge-margin is definitely straight along the middle third or more of the dorsal edge, with the hinge-angles more or less defined, and is oblique to the main axis of the valve. The left valve is the largest, and receives the dorsal edge and a straight ridge of the other valve in grooves on its dorsal and ventral contact-margins, the outer edge of the ventral margin of the left valve overlapping that of the right valve. The ridges and furrows or ledges of contact vary in intensity in different individuals.

1. Cypridea valdensis (Fitton). [Not figured here.]

Cypris faba, Sow. (not Desmarest). Annals of Philos. vol. viii. 1824, p. 376; Min. Conch. 1824, tab. 485, pp. 136–8.

Cypris valdensis, Fitton, Trans. Geol. Soc. 2 ser. vol. iv. 1836, p. 177 (not pl. 21. fig. 1).

Cypris valdensis, Römer, Verst. norddeutsch. Oolithengebirg. 1839, p. 52, pl. 20. fig. 20 (*C. punctata*, Forbes).

Cypris valdensis, Dunker, Monogr. nordd. Wealdenbild. 1846, p. 59, pl. 13. fig. 29 (copied from Sowerby's figure?).

Cypridea valdensis, Jones in Morris's Catal. Brit. Foss. 2nd edit. 1854, p. 104.

Cypridea valdensis, Huxley & Etheridge, Catal. Foss. Mus. Pract. Geol. 1865, p. 254, 270.

Cypridea valdensis, H. Woodward, Catal. Brit. Foss. Crust. 1877, p. 89.

Cypridea valdensis, Jones, Geol. Mag. 1878, p. 109, pl. 3. fig. 11 (not fig. 13–15).

Largest specimen $1\frac{1}{2}$ mm. long (Wealden). Largest Purbeck specimen $1\frac{1}{8}$ mm.

J. De C. Sowerby's original figure and description in the 'Mineral Conchology' give very satisfactorily the shape and main characters of this species, although it often attains somewhat more bulky proportions. As noticed by Sowerby and Fitton, it is very plentiful in many of the true Wealden strata. They thought that they found it also in several of the Purbeck beds; but in this they were certainly mistaken, for Fitton's labels (in the Geol. Soc. Museum) show that he mistook *C. purbeckensis* and *C. punctata* for it. In one of the Purbeck beds, however, there are some few specimens, large, smooth, and elegantly shaped, quite different from the thicker and coarser *C. punctata*, which has often been mistaken for it. The stratum referred to is the Chert Bed of the Middle Purbeck, Ridgway, in which occur—

Cypridea valdensis.	Metacypris Forbesii.
—— punctata (rare).	Chara, seed-vessel.
Darwinula leguminella.	Fishbone, &c.

There are also some doubtful instances of its occurrence in the deep "Purbecks" of Mid-Sussex.

2. Cypridea punctata (E. Forbes).

[Only the insides of valves are figured in Pl. VIII. figs. 4 & 5; the outsides resemble figs. 1–3, 6, 8 in shape, without their varietal and distinctive features.]

Cypris punctata, Forbes, MS. July 23, 1854.

Cypris punctata, Forbes in Lyell's Manual of Elementary Geology, 5th edit. 1855, p. 297, fig. 339 *b*; id. Elements of Geology, 6th edit. 1865, p. 387, fig. 375 *b*.

Cypridea valdensis, Jones, Monogr. Fossil Esth. 1862, p. 127, pl. 5. figs. 26–30.

Cypridea punctata, Huxley & Etheridge, Catal. Coll. Foss. Mus. P. Geol. 1865, p. 254.

Cypridea punctata, H. Woodward, Catal. Brit. Foss. Crust. 1877, p. 89.

Cyprida valdensis, Jones, Geol. Mag. 1878, p. 110, pl. 3. figs. 13–15.

Length $\frac{3}{4}$ mm., and 1 mm.

Valves subtriangularly obovate, nearly obovate, or subpyriform, varying in the protuberance of the anterior hinge-joint. Both the front and the hind margin are obliquely rounded; but the latter is more contracted than the former. Convex medially; edge-view narrow-oval. Surface punctate; punctations subcircular, easily seen with a lens (see also E. Forbes's letter to Mr. Bristow, above, p. 314). The outer edge of the ventral margin of the left valve overlaps that of the right valve.

Notch and beak distinct, and often strong, but varying in intensity.

This species is broader (higher) and coarser than the typical *Cypridea valdensis* (Fitton), figured by J. De C. Sowerby in the 'Mineral Conchology,' pl. 485 (December 1824*), described there at pp. 136–138, and referred, with doubt, to *Cypris faba*, Desmarest. The small (young) forms accompanying adult specimens of *C. punctata* (no. 159) very much resemble *C. valdensis*.

It is quite probable that some of the coarser valves referred to *C. valdensis* by authors are really *C. punctata*, such as figs. 13, 14, 15, pl. iii. Geol. Mag. dec. 2. vol. v. from the Subwealden Boring in Sussex.

2*. Cypridea punctata (Forbes). Var. posticalis, nov. (Pl. VIII. figs. 1–3, 6, 8.)

Length generally 1mm. Fig. 8 represents a specimen $\frac{7}{8}$ mm. long.

Although *C. punctata* often has a neat acute-oval edge-view, yet very many individuals have the posterior extremity of each valve thickened with a more or less pronounced marginal lump, thick and round, low and broad, or narrow and faint, giving a blunt end to the edge-view (fig. 3). The close-set subangular or subcircular punctations are usually strongly marked.

2**. Cypridea punctata (Forbes). Var. gibbosa (Forbes). (Pl. VIII. fig. 7.)

Cypris gibbosa, Forbes, MS. July 18, 1851.

Cypris gibbosa, Forbes in Lyell's Manual Elem. Geol. 5th edit. 1855, p. 294, fig. 334 *a*; id. Elem. Geol. 6th edit. 1865, p. 378, fig. 368 *a*.

Cypridea gibbosa, H. Woodward, Catal. Brit. Foss. Crust. 1877, p. 88.

Length $\frac{7}{8}$ mm.

Here the middle of the valve is locally swollen; this is a variable feature, not strong in fig. 7. See Forbes's letter, above, p. 314. The specimen here figured is nearly obovate in outline, and has a slightly thickened posterior edge (as in the foregoing var. *posticalis*).

* See "Dates de la publication des Espèces," &c., par M. E. Renevier, 'Bullet. Soc. Vaudoise Scienc. Nat.' 2 Mai, 1855.

In specimen Xʙ$\frac{5}{3}$ Mus. Pract. Geol., the central swelling is well marked, without any posterior thickening of the valve.

3. Cypridea Dunkeri, sp. nov. (Pl. VIII. figs. 9, 10, and 17.)

Cypridea granulosa, Römer (non Sowerby), Verst. nordd. Ool.-Geb. 1839, p. 52, pl. 20. fig. 24.

Cypris granulosa, Dunker (non Sowerby), Monogr. nordd. Wealdenbild. 1846, p. 60, pl. 13. figs. 31 *a*, *b*.

Cypris granulosa, Forbes (non Sowerby), MS. July 18, 1851.

Cypris granulata, Forbes, MS. July 23, 1854.

Cypris granulata, Forbes, in Lyell's Elem. Man. Geol. 5th edit. 1855, p. 295, fig. 337 *c*; Elem. Geol. 6th edit. 1865, p. 378, fig. 371 *c*.

Cypridea granulosa, H. Woodward (non Sow.), Cat. Brit. Foss. Crust. 1877, p. 88.

Length $\frac{3}{4}$ mm.

This has the obovate form and general features of *C. punctata*, but it possesses granules or small tubercles scattered irregularly over the surface. This is shown in Forbes's letter of July 18, 1851, but too roughly. In our figured specimens the tubercles vary in size, being feeble in the neat, small, nearly symmetrical figs. 9, 10, and strong in the larger and coarser fig. 17. In one individual (fig. 10) the punctation consists of small and rather oblong pits on the anterior third of the valve, with an obscurely radiate arrangement. Taking both Purbeck and Wealden specimens of this species in view together, we find much variation in convexity and in tubercles; occasionally some of these are sharp (near Brook Point).

This subovate, or rather obovate, form has been confused with the suboblong *Cypridea granulosa* (Sow.). The latter is distinguished by its larger size, more oblong shape, and the tendency of its granules to leave the middle of the valve bare. This is plentiful in the Middle Purbeck, whilst the obovate form, with granules distributed over the whole surface, is rare in the Purbecks *; and this agrees with E. Forbes's note to Mr. Bristow (see above, p. 314).

In consequence of the confusion of names, I now dedicate this species to the memory of my late friend Dr. W. Dunker, of Marburg, by whom it was figured and described much more clearly and perfectly than by his predecessor F. A. Römer.

Cypridea Dunkeri is rare in the Upper and Middle Purbeck, but of rather more frequent occurrence (though rarely common) in the Wealden beds. It is met with in the Upper Purbeck at Mewps Bay (specimen Xʙ$\frac{5}{3}$, M.P.G.), and at Durlston Bay, specimen no. 40. In the Middle Purbeck it occurs at Ridgway (Xʙ$\frac{4}{5}$, M.P.G.); also in a specimen, given to me by the Rev. O. Fisher, and probably from Mewps Bay, there associated with *Cytheridea punctata*, var. *posticalis*, *Metacypris Forbesii*, and *Darwinula leguminella*.

The synonyms indicate that it also belongs to the black Cypridiferous shales of North Germany (see also above, p. 319).

* Except at Swindon, see p. 330.

4. Cypridea ventrosa, sp. nov. (Pl. VIII. figs. 25, 26.) And var. globosa.

Length 1 mm.

Valves thick and broad (high); obovate, with one edge (ventral), notched and less convex than the other; broadest (highest) at the anterior third; back elliptically rounded, with some protuberance at the anterior hinge, and a steep antero-dorsal slope. The ventral region has its border slightly curved, oblique, fuller in front, and broadly notched; and it is turned in suddenly so much as to form a broad flat base, on which the carapace can stand upright. The surface bears some irregularly placed coarse tubercles and ridges, the latter being on the ventral region, and having a direction in general parallel or conformable with the ventral and anterior borders. The beak comprises the anterior curved ridge much more definitely than shown in fig. 26. Edge-view subovate.

C. ventrosa has a near ally in *C. verrucosa*, var. *crassa*, Jones (Geol. Mag. 1878, p. 108, pl. 3. fig. 4), which should (I think) now be regarded as a distinct species (*C. verrucosa*; see page 320).

In specimen 44 the typical *C. ventrosa* is accompanied by a variety (*globosa*) which is quite smooth, and in some cases almost loses its ventral lateral projection, though retaining a strong gibbosity. The flat ventral base in *C. ventrosa* reminds me of a somewhat similar, but more regularly constructed feature in *Notodromas*, Lilljeborg (*Cyprois*, Zenker, and *Newnhamia*, King).

C. ventrosa is found in the Middle Purbeck, together with its var. *globosa*; and it occurs also in the Upper Purbeck: at Durlston Bay in both cases.

5 & 5*. Cypridea granulosa (Sow.); and var. fasciculata (Forbes); and var. paucigranulata, nov. (Pl. VIII. figs. 18–21.)

Cypris granulosa, Sow. 1836, Trans. Geol. Soc. ser. 2, vol. iv. pp. 177 (?), 260, 345, pl. 21. fig. 4,

Cypris granulosus, Mantell, Wonders of Geology, 1838, vol. i. p. 344, tab. 46. fig. 9 (fig. 7 is a bad copy of a part of Fitton's fig. 1, and fig. 9 of part of Fitton's fig. 4). *Cypris granulosa*, Mantell, Wonders, 3rd edit. p. 77, fig. 9, and 6th edit. 1848, vol. i. p. 405, lign. 98, fig. 3 (as fig. 9 above).

Cypris granulosa, Mantell, Wonders, 7th edit. (T. R. Jones), 1857, vol. i. p. 419, lign. 104, fig. 2.

Cypris granulosa, Mantell, Medals of Creation, 1844, vol. ii. p. 545, lign. 119, fig. 4; and 2nd edit. 1854, vol. ii. (T. R. Jones), p. 527, lign. 174, fig. 4.

Cypris fasciculata, Forbes, MS. July 18, 1851, & MS. July 23, 1854.

Cypris fasciculata, Forbes, in Lyell's Manual Elem. Geol. 5th edit. 1855, p. 295, figs. 337 *b*; Elements of Geology, 6th edit. 1865, p. 378, figs. 371 *b*.

Cypridea granulosa, Morris, 1854, Catal. Brit. Foss. p. 104 (omitting Dunker's synonym and the reference to *Wealden*).

Cypridea granulosa and *C. fasciculata*, H. Woodward, Catal. Foss. Crust. 1877, p. 88.

Cypridea verrucosa (var.), Jones, Geol. Mag. dec. 2, vol. v. 1878, p. 108, pl. 3. fig. 6.

Length 1 mm.

Suboblong or broadly obovate; anterior end obliquely and boldly rounded, posterior somewhat narrower and nearly semicircular; hinge-line slightly oblique, having the front hinge-joint at an obtuse angle. Beak and notch not always strongly developed. Contact-margins flanged and furrowed, nearly continuously, and subject to difference of intensity in individuals. Edge-view of carapace narrow-ovate; end-view oval. The surface punctate, and also granulated. The pitting consists of either subcircular pits, as on a thimble, or minute suboblong pits, almost forming a reticulate pattern. In no cases that I have seen are the granules distributed over *all* the surface, the median region always having fewer (as in Sowerby's figure 4, pl. 21, in Fitton's Memoir), and often none (see Pl. VIII. fig. 18). The granules are always grouped in two sets or fascicules, one on the anterior and one on the posterior third of each valve; hence the appropriate name "*fasciculata*" given by E. Forbes to this dominant Mid-Purbeck species. The number of granules in these local groups is variable, as above intimated. Sowerby's type-figure has many granules, some coming near to the middle of the valve; other specimens collected by Fitton, and labelled with Sowerby's name, have very few granules. There is no line to be drawn, so far as essential characters are concerned, between the multigranulate and paucigranulate modifications; but it will be convenient to recognize the varieties. In the Mid-Purbeck beds of Durlston Bay both abound, and at Teffont (No. 38), the multigranulate forms predominate. At Dashlet (also in the Vale of Wardour), and at Whitchurch, in Bucks, the paucigranulate variety occurs plentifully (figs. 8–20). In specimens (M.P.G.XB$\frac{4}{2}$) from the Mid-Purbeck of Durlston Bay the valves are mostly paucigranulate; one, at least, has the hinder fascicule obsolescent. They have a coarsely punctate or subreticulate surface. Some strong, squarish, convex individuals from Dashlet have very few tubercles, only five, or even four, in the fascicules; and the punctation takes on a partially regular pattern, the pits on the anterior half of the valve being oblong and even elongate, curving round in front and radiating backwards for a little way from the anterior group of five granules. Even without regarding the modified punctation, these specimens may be looked on as a variety, *paucigranulata*; whilst the ordinary multigranulate forms divide themselves into the common variety *fasciculata* (Forbes), and the rarer and earliest named *granulosa* of Sowerby with the granulation covering almost the whole surface. The name *fasciculata* has been, and still continues to be, convenient for general use.

C. granulosa (Sow. in Fitton, pl. 21, fig. 4, of Fitton's Memoir), is decidedly the *fasciculata* of E. Forbes, and its localities are there given (p. 260) thus:—"Between Dallard's Farm and Catharine

Ford, with *Cyclas* in slaty Purbeck stone; also, with *Cyclas* and *Modiola*, in grey freshwater limestone. Dashlet, between Penthurst and Teffont."

In two multigranulate specimens from Teffont (No. 83) the "lucid spots" ("muscle-spots") are visible, consisting of six suboblong marks, three in a short, slightly curved, transverse row, one lying behind and across them, and two others separate, at a little distance from the ends of the aforesaid row.

This species is highly characteristic of the Middle-Purbeck beds, both by its abundance and by its being peculiar to that division of the series.

Some forms of *Cypridea verrucosa*, Jones, 1878, were separated from *C. granulosa* (Sow.) on account of the supposed absence of the beak and notch in the latter; but one of these (fig. 6, pl. iii., Geol. Mag. 1878) is evidently the same as the *granulosa* (multigranulate) we have before us, and now know to have the notch.

This essentially Mid-Purbeck species certainly occurs in the Cypridiferous shales of Obernkirchen, Cassel, North Germany (specimens in the British Museum), although it is not described nor figured by Römer and Dunker. It is of much interest, as supporting the late Dr. W. Dunker's opinion that the Hanoverian shales are of *Purbeck* and not of *Wealden* age.

6. CYPRIDEA TUBERCULATA (Sowerby); and var. ADJUNCTA, nov. (Pl. VIII. figs. 22, 23, 24.)

Cypris tuberculata, J. De C. Sow., in Fitton's Memoir, Trans. Geol. Soc. ser. 2, vol. iv. 1836, pp. 177, 205, 228, 345, 352, pl. 21, fig. 2 (including another form, indicated in the description at p. 345, and subsequently separated off as *Cypris Fittoni* by Mantell).

Cypris tuberculata, Lyell, Elements of Geology, 1838, p. 348, fig. 186 (after Sowerby); 2nd edit. 1841, vol. i. p. 417, fig. 202; Manual of Elementary Geology, 3rd edit. 1851, and 4th edit. 1852, have the same woodcuts as the foregoing; 5th edit. 1855, p. 294, fig. 334 *b* (after E. Forbes); 6th edit. 1865, p. 378, fig. 368 *b*.

Cypris tuberculata, Römer, Verst. nordd. Ool. 1839, p. 52, pl. 20. fig. 23.

Cypris tuberculata, Mantell, Medals of Creation, 1st edit. 1844, vol. ii. p. 545, lign. 1819, figs. 3, 3*a*; 2nd edit. (Jones), 1854, vol. ii. p. 527, lign. 174, figs. 3, 3*a* (fig. 2 is *C. Fittoni*, Mantell, in both cases).

Cypris tuberculata ?, Dunker Monogr. nordd. Weald. 1846, p. 60, pl. 13. fig. 30.

Cypris spinosa, Forbes, MS., July 18, 1851; *C. tuberculata* ?, MS., July 23, 1854.

Cypridea tuberculata, Morris, Catal. Brit. Foss. 2nd edit. 1854, p. 104.

Cypridea tuberculata, H. Woodward, Catal. Brit. Foss. Crust. 1877, p. 89.

Length $\frac{3}{4}$ millim.

This is one of the suboblong forms of the genus, slightly broader (higher) in front than behind, and more boldly and obliquely curved anteriorly than posteriorly; the dorsal and ventral margins nearly parallel; the notch often strong, but sometimes obscured by tubercles; the contact-margins are much like those of *C. granulosa* (fig. 21); the beak sometimes almost obsolete, but traceable. The surface is punctate, with coarse, subcircular, close-set pits, giving an appearance like that of a thimble-top; it also bears numerous, large, scattered tubercles, somewhat variable in their strength and position; occasionally long, thick, and blunt, as noticed in E. Forbes's letter to Mr. Bristow, see above, p. 314, where he terms it "*C. spinosa*." Specimen X$\text{B}\frac{4}{2}$, Mus. Pract. Geol., shows an individual of this kind, with long thick tubercles; it is strongly beaked, much more so than our fig. 22, Pl. VIII. In fact this specimen is rather longer than the typical form, and is less strongly beaked; and it ought to be regarded as a variety, *adjuncta*.

Edge-view long-ovate; end-view short-ovate (figs. 23 and 24).

The coarse tubercles remind us of a similar feature in *Cytheridea torosa* (Jones); but in the latter they are fewer and relatively larger, and the hingement of the valves is different.

C. tuberculata is not common. It comes from the Mid-Purbeck of Durlston Bay (X$\text{B}\frac{4}{2}$, M. P. G.); and from the Upper Purbeck of Mewps Bay (specimen no. 27, fig. 22, Pl. VIII.), and of Bacon Hole (specimen in the British Museum, and X$\text{B}\frac{5}{2}$, M. P. G.). This last is like the Wealden specimens figured in Fitton's Memoir, which are strictly Wealden, but do not occur nearly so frequently as *Cythere Fittoni* (Mantell), which was figured with them in fig. 2, pl. 21, of Fitton's Memoir, and has been often mistaken for *C. tuberculata*.

The Purbeck form (var. *adjuncta*) occurs also, I believe, in the Wealden beds, Eccleston Glen, Hastings. The Wealden species I hope to treat in full at a future opportunity.

Römer, 1839, evidently had *C. tuberculata*, Sow., in the black Cypridiferous Shales of North Germany, and Dunker, in 1846, repeats the observation; but his figure is very doubtful.

II. Genus Cyprione, gen. nov.

Animal unknown. Carapace bivalved; subcylindrical; right valve rather larger than the other; contact-margins ridged and furrowed almost continuously, but the flanges and corresponding ledges run closer together in some specimens than in others. Hinge-line along the slightly convex back-edge not specially defined. Valves smooth, elongate-oblong, with rounded ends, in the only species yet recognized.

The structure of the contact-margins of these valves is not essentially different from that in *Cypridea*, except that the latter has its characteristic antero-ventral notch. *Cypridea*, moreover, has much coarser and thicker valves, and always differs in shape.

The outlines of the carapace under notice approach those of *Darwinula*; but in the latter the valves meet with simple edges and considerable overlap; and, as no other genus among the Ostracoda

is characterized by this elongate and slightly tapering oblong shape, it seems advisable to take this feature and the contact-margins as giving the leading characters for a separate genus *Cyprione*.

7. CYPRIONE BRISTOVII, sp. nov. (Pl. VIII. figs. 27–29, and 32, immature.)

Length, adult 1 millim.; immature, $\frac{5}{8}$ millim.

Valves suboblong, elongate, with rounded ends, the anterior rather narrower than the other. The ventral somewhat straighter than the dorsal edge. The valves meet with slight ridges and furrows. The right valve overlaps the other nearly all round, although the figs. 28 and 29, being taken from odd valves, do not give this impression.

This may be the larger form, of a peapod-shape, which E. Forbes referred to in his letter (to Mr. Bristow) of July 18, 1851 (see p. 314). I name it after Mr. Bristow, F.R.S., F.G.S., Director of the Geol. Surv. of England, who worked so long and ardently on the Purbeck strata with his friend E. Forbes.

Cyprione Bristovii is met with in the Upper Purbeck (specimens —40, 40 A, 40 AA, Durlston Bay; 27, Mewps Bay, young form, fig. 32, Pl. VIII.); and in the Mid-Purbeck (44 and 56, 57, 58, Durlston Bay).

It occurs in the Wealden Beds, at the Black-Horse Quarry, near Hastings, and also near Bexhill, and at Lindfield.

In Germany it is found at Obernkirchen and the Deister, as shown by specimens in the British Museum. The "*Cypris oblonga*" of Römer and Dunker may possibly have been intended for this and *D. leguminella* (see above, p. 319); but the figures and descriptions are obscure and contradictory. Certainly fig. 34, pl. 5, Monogr. Foss. Esth., Appendix, p. 128, may be a near ally of *C. Bristovii*; but it best agrees with Römer's description of his *C. oblonga*, though not with his figure. The latter is too much arched on the back for *C. Bristovii*, and should be regarded as *Cyprione*? *oblonga* (Römer).

III. Genus METACYPRIS, G. S. Brady, 1870.

Metacypris, G. S. Brady, Nature, March 10, 1870, p. 484.

Metacypris, G. S. Brady and Robertson, Ann. & Mag. Nat. Hist. ser. 4, vol. vi. July 1870, pp. 19, 20; *Ibid.* vol. ix. 1872, p. 51; and Monogr. Post-tertiary Entom., Pal. Soc. 1874, pp. 112 and 116.

Valves subrhomboidal or suboblong, very convex; rounded before and behind, but unequally and somewhat obliquely; rather narrower and compressed in front; dorsal and ventral margins nearly parallel, but the latter turned inwards, or pressed in along the hinder half of its length, so that the body of each valve swells out beyond it. Hinge-line distinct, with thin flanges and narrow furrows; but our fossils do not show the details so well as the recent specimens of *M. cordata*, Ann. & Mag. N. H. 1870, pl. 6. The right valve is larger than the left. The surface is pitted in lines.

Only one recent species is known (see above); found in tidal rivers in the East of England. This genus was at first placed with the Cypridæ with doubt, but afterwards referred more certainly to the Cytheridæ†.

8. METACYPRIS FORBESII, and var. VERRUCOSA, sp. et var. nov. (Pl. VIII. figs. 11–16.)

Cypris striato-punctata, Forbes (non Römer et Dunker), MS. July 18, 1851; MS. July 23, 1854; Lyell's Manual Elem. Geol. 5th edit. 1855, p. 295, fig. 337*a*; Elem. 6th edit. 1865, p. 378, fig. 371*a*.

Cypris striato-punctata, Huxley and Etheridge, Catal. Coll. Foss. Mus. P. Geol. 1865, p. 254.

Cypridea striato-punctata, H. Woodward, Cat. Brit. Foss. Crust. 1877, p. 89.

Figs. 11–14: length $\frac{5}{8}$ millim.; figs. 15 and 16, $\frac{3}{4}$ millim.

This is remarkably like *M. cordata*, G. S. Brady (Nature, *l. c.*), above referred to, but it is less convex, and is longer in proportion to breadth (height); and it shows a strong tendency to become tubercled. The ornamental pitting may be described in Dr. Brady's words:—"Surface of the valves closely set with small rounded impressions, which are arranged in longitudinal rows, running on the ventral surface into interrupted furrows; ventral surface deeply and broadly sulcate along the greater part of the median line." We may add that the lines of dots, in both cases (recent and fossil) curve round on the front third of the valve, and in the fossil specimens they have a slight local swelling or a tubercle for their centre. The linear ornament curves round also (but less distinctly) behind, parallel with the posterior border. Edge-view, subovate or bluntly pyriform. End-view short, broad, ovate.

As E. Forbes seems to have referred this species (sufficiently well indicated in his letter to Mr. Bristow, see above, p. 314) erroneously to Römer's species, and as the surface character in both the recent and this fossil species is striato-punctate, I do not hesitate to give it a new name, dedicating it to the memory of the much-lamented palæontologist and geologist who worked out the three main divisions of the Purbeck series, as characterized by the fossils, among which especially were Ostracoda treated of in this paper. Prof. Dunker agreed with me in regarding this species as quite distinct from *Cypridea striato-punctata* (Römer), which may, I think, be possibly a variety of, or near ally to, *C. valdensis* or *C. punctata*.

8*. M. FORBESII, var. VERRUCOSA. (Figs. 12 and 14.)

Here we have the tendency towards tuberculation carried to the full, that is, as far as yet observed; and the individuals are not

† Egger's *Bairdia glutæa*, from the Miocene beds of Mairhof, near Ortenburg, in Lower Bavaria ("Die Ostrakoden der Miocän-Schichten," &c. in the 'Neues Jahrbuch f. Min.' &c. 1858, p. 408, pl. 1. fig. 6), has evidently the characters of this genus.

quite so nearly oblong in outline, being somewhat narrowed in front.

Metacypris Forbesii comes from Durlston Bay (specimens $X_B\frac{4}{6}$, M.P.G.); from Ridgway ($X_B\frac{4}{5}$, M.P.G.), and No. 123A, Ridgway, also No. 61, Mewps Bay. All these are from the Middle Purbeck.

IV. Genus Darwinula.

[Note by G. S. Brady, M.D., F.R.S., F.L.S., and D. Robertson, F.L.S., F.G.S., June 12, 1885.

"Prof. T. Rupert Jones having kindly drawn our attention to the fact that the generic term *Darwinella* had already been appropriated by Fritz Müller, in 1865, for a genus of horny sponges (Schulze's Archiv für mikr. Anat. vol. i. p. 344), and *Darwinula* having been suggested as appropriate, we are glad to have the opportunity of adopting this suggestion and substituting the latter term."]

Polycheles, G. S. Brady, Nature, March 10, 1870, p. 484.

Polycheles, G. S. Brady and D. Robertson, 1870, Ann. & Mag. Nat. Hist. ser. 4, vol. vi. July 1870, p. 25.

Darwinella, Brady and Robertson, 1872, Ann. & Mag. Nat. Hist. ser. 4, vol. ix. p. 50, note; and vol. xiii. 1874, p. 117; and Monogr. Post-tertiary Entom., Pal. Soc. 1874, pp. 112, 140.

Carapace smooth, subcylindrical, elongate, oblong-ovate, or subcuneate; valves thin and smooth, unequal, right larger than the left valve.

Only one recent species (*D. Stevensoni*, B. and R., *locc. citt.*) is known. It belongs to the brackish waters of tidal rivers. This or a very similar species has been found in the Forest-bed series of Suffolk by Mr. Clement Reid, F.G.S., of the Geological Survey.

9. Darwinula leguminella, Forbes. (Pl. VIII. figs. 30 and 31.)

Cypris oblonga (?), Dunker, Monogr. nordd. Weald.-Bild. 1846, p. 60, pl. 13. fig. 24.

Cypris leguminelloides, Forbes, MS. July 18, 1851.

Cypris leguminella, Forbes, MS. July 23, 1854; Forbes, in Lyell's Manual of Elem. Geol. 5th edit. 1855, p. 294, fig. 334*c*; Elements Geol. 6th edit. 1865, p. 378, fig. 368*c*.

Cypridea oblonga?, Jones, Monogr. Foss. Esther. 1862, p. 128, pl. 5. fig. 31 (and 33 ?).

Cypridea leguminella, H. Woodward, Cat. Brit. Foss. Crust. 1877, p. 89.

Length $\frac{1}{2}$ millim.

Valves small, smooth, shining, elongate, with rounded ends, one (anterior) narrower, more elliptically curved, and more compressed than the other; the left valve the largest. Carapace subcylindrical, tapering anteriorly, blunter behind.

This is very much like the Carboniferous *Darwinula berniciana*, Jones, 'Proceed. Berwicksh. Nat. Club,' vol. x. 1884, p. 325, pl. 2, fig. 4; but it is not so truncate posteriorly, and is slightly more

acuminate in front. It still more closely resembles the recent *D. Stevensonii*, B. C. and R.; and it is possibly identical with fig. 31, pl. 5, of my 'Monogr. Foss. Estheriæ,' 1862, Appendix, p. 128, though a little smaller. This last is a small valve from the Wealden of Obernkirchen, Cassel, near Hanover, and was very superficially described, together with other associated fossil valves, in the Appendix referred to. In 1878 (Geol. Mag. dec. 2, vol. v. p. 107) I made some remarks on these specimens. Fig. 30 is probably a *Candona*; fig. 31 a *Darwinula* * (see above); fig. 32 is obscure; fig. 33 may be an impaired specimen of *Darwinula* (?); and fig. 34 may be *Cyprione? oblonga* (Römer).

D. leguminella (E. Forbes) has been found in the following Upper-Purbeck specimens, 397 A and 397 B, Durlston Bay; XB$\frac{5}{2}$ and Brit. Mus. Bacon Hole; 61, 377, and 378, Mewps Bay. In Middle Purbeck XB$\frac{4}{3}$ & XB$\frac{4}{2}$, Durlston Bay, and 123 A, Ridgway.

It occurs also in the Wealden Beds, near Atherfield, Sandown, Hastings, Hythe, &c. See pp. 333, 334.

D. leguminella abounds in some of the Hanoverian black Cypridiferous Shales from Obernkirchen and the Deister. Some specimens are in the British Museum. Although the description and figures of *Cypris oblonga* given by Römer and Dunker do not fit this species, yet it is possible that they were intended to cover both it and *Cyprione Bristovii*; *C. oblonga* (Römer), however, may be distinct. At all events Dunker's fig. 24 well suits a piece of shale loaded with little *Darwinulæ*. The species is figured in my 'Monogr. Foss. Esth.' *l. c.* from Obernkirchen, Hanover; fig. 31 is fairly good, and fig. 33 may be imperfect or partly imbedded.

V. Genus Cypris, Müller, 1785.

(See the memoirs on recent Ostracoda, by G. S. Brady and others, to whom he refers, for general and special descriptions.)

Valves subreniform or suboblong, thin, smooth, pitted or bristly; hinge simple, or with narrow furrows or flanges and slight ridges. The interiors of the front and hind margins are bevelled, and are sometimes continued into a more or less developed, narrow, laminar, oblique plate. Left valve the largest.

10. Cypris purbeckensis, Forbes. (Pl. IX. figs. 1–6.)

Cypris purbeckensis, Forbes, MS. July 18, 1851; MS. July 23, 1854.

Cypris purbeckensis, Forbes, in Lyell's Manual Elem. Geol. 5th edit. 1855, p. 297, fig. 339*a*; Elem. Geol. 6th edit. 1865, p. 387, fig. 375*a*.

Cypris purbeckensis, Huxley and Etheridge, Catal. Coll. Foss. Mus. P. Geol. 1865, p. 254.

Cypris purbeckensis, P. de Loriol et Jaccard, Mém. Soc. Phys. Hist. Nat. Genève, vol. xviii. part i. 1866, pp. 81, 82, pl. 2. figs. 1–3.

* Figs. 23 and 24 in the same plate (*Candona? globosa*, from Linksfield) may represent a *Darwinula* also; for its lucid spot, of which I have drawings, is that of *Darwinula*.

Cypridea purbeckensis, H. Woodward, Catal. Brit. Foss. Crust. 1877, p. 89.

Cypris? purbeckensis, Jones, Proceed. Geol. Assoc. vol. viii. 1883, pp. 57, 58.

Length $\frac{7}{8}$ mm. figs. 3–5; 1 mm. figs. 4 & 6; $1\frac{1}{4}$ mm. fig. 1; $1\frac{1}{2}$ mm. fig. 2.

Valves subreniform, arched on the back; nearly straight, or somewhat incurved, on the ventral edge; rounded at the ends, broadly and obliquely in front. Edge-view acute-oval. Surface smooth. Contact-margins simple. Insides of front and hind margins are sometimes more bevelled than in fig. 1.

The size and shape are both rather variable (compare figs. 1–6, Pl. IX). An exceptionally broad (high) left valve, with a remarkable sharp tubercle (local hypertrophy?) on the postero-dorsal edges, is shown by fig. 6. Figs. 3 and 5 are smaller *reniform* individuals. Age and sex probably determined these differences of size and shape.

A broken valve from the Post-tertiary freshwater beds at Copford, Essex, is figured (hind end upwards) in my 'Monograph Entom. Tert. Form.' 1856, pl. 1, fig. 5*a*, which closely approximates in form to fig. 1 of Pl. IX. here. It is the variety *tumida*, B.C. and R., of *Candona candida*. *Cypris virens* (Jurine), known also as *C. tristriata*, Baird, is a recent form of very similar make, and in G. S. Brady's "Monogr. Rec. Brit. Ostrac.," Trans. Linn. Soc. vol. xxvi. pl. 23. figs. 23–26, it is figured witn the little gape seen also in our fig. 4, Pl. IX.

On the specimen in the Mus. Pract. Geol., X B$\frac{4}{7}$, probably one of the early slabs seen by E. Forbes, there are the two somewhat differing forms, namely, the *reniform* and the *subreniform*. They have all been weathered, and one side-surface has especially been thus modified, so as to account for the flat margin in the figure given by Lyell, and in one of those in Forbes's two letters. This specimen is referred, by error I believe, to the Middle instead of to the Lower Purbeck in the Museum of Practical Geology (see above, p. 325 *note*).

VI. Genus Candona, Baird, 1845.

Valves like those of *Cypris*. Difficult to be distinguished from that genus except by comparison with known recent forms, the structure of the soft parts supplying the critical differences. The general aspect of the Purbeck specimens here selected under this head reminds us of *Candonæ* rather than of *Cyprides*.

11. Candona bononiensis (corrected, see above, p. 311), Jones. (Pl. IX. figs. 7, 8.)

Cythere boloniensis, Jones, 1882, Bullet. Soc. Géol. France, sér. 3, vol. viii. pp. 615, 616, 1883; Proceed. Geol. Assoc. vol. viii. p. 58.

Length $1\frac{1}{4}$ mm.

Valves suboblong, almost equally rounded at the ends, constricted a little in front of the middle, the posterior moiety being higher and

more convex than the front portion. Edge-view of carapace acute-ovate. Left valve the largest. Contact-margins simple; the nearly straight dorsal edge has the front hinge indicated by a slight angle and a faint impression behind it outside.

12. CANDONA ANSATA, sp. nov. (Pl. IX. figs. 9–12.)

Length $\frac{3}{4}$ mm. to $\frac{7}{8}$ mm.

Valves suboblong, obliquely rounded at each end, the slopes being antero- and postero-dorsal. Back straight; ventral edge slightly concave, with its edge turned in at the middle and swelling out at the posterior third, so as to form a strong projection, almost like the short, blunt handle of a crock (but upside-down). The surface is smooth; but in some cases the inside of the valve is pitted (by the decay of tubules?), and the bevelled translucent insides of the front and hind margins show radiating tubules (fig. 9). Lucid spots are visible in figs. 9–12, somewhat resembling those in *Cytheridea*. Edge-view of the carapace suboval. Left valve the largest. The contact-margins are simple; terminal edges bevelled inside; hinge-line distinct, with a faint angle in front (not strong enough in fig. 9), and a slight impression behind it on the outside.

The "lucid spots" are visible in a specimen from Hartwell (No. 269).

They form a pattern of six; four transverse, parallel, in a curve (convex backwards), and two in front, one near each end of the lower row.

VII. Genus CYTHERE, Müller, 1785.

Carapace of two nearly equal valves, suboblong, subrhomboidal, or subtriangular, thick, ornamented with pits, reticulation, riblets, and tubercles. Left valve usually rather larger than the right. Inside of the front edges in each valve bevelled off inwards. Hinge, for the most part, a barlike ridge on the left valve, ending in front with a tooth and a socket beyond, and ending behind at the socket which receives the tooth at the end of the furrow on the right valve behind the anterior tooth which falls into the front socket of the left valve. So that, typically, the left valve has a bar and front tooth, and a socket at each end; whilst the right valve has a corresponding sulcus and socket and a tooth at each end, besides a thin outer ledge or flange to fall into a furrow along the outer convexity of the wider left valve. Some of these features are often modified or obsolete. See examples in the Monogr. Tert. Entom., Pal. Soc. 1856. For the relationship of recent species, as based on the soft parts, see the memoirs by Sars and Brady on Ostracoda—for instance, G. S. Brady's "Report on the Ostracoda dredged by H.M.S. 'Challenger,'" &c. 'Zool. Chall. Exped.' pt. 3, 1880, pp. 61–62.

13. CYTHERE TRANSIENS, sp. nov. (Pl. IX. figs. 13–16.)

Length $\frac{1}{2}$ mm.

Valves subtriangular, or somewhat pear-shaped, rounded at ends,

high on the back at the anterior third, where the front hinge somewhat projects. Edge-view blunt, compressed oval. Surface coarsely pitted with a rough reticulation. Ventral edge much incurved.

Found at Swindon (specimen no. 364), in Purbeck beds, by the Rev. Prof. J. F. Blake, F.G.S., after whom it was at first named (when this paper was read); but another *Cythere* had already been assigned to him. *C. transiens* occurs also in a soft, white Portland stone from Brill.

14. Cythere retirugata, sp. nov. (Pl. IX. figs. 17–24, including var. *rugulata*, figs. 17–20; and var. *textilis*, fig. 24.)

Length usually $\frac{3}{4}$ mm., fig. 19, $\frac{7}{8}$ mm.

Suboblong, with oblique ends, sloping from the front and hinder ends of the hinge-line, which is straight, and oblique to the long axis of the valve. Ventral border slightly sinuous, and much incurved at its edge. Edge-view oval, slightly acute. Surface pitted over two thirds of its area, and wrinkled or finely costulate along the ventral region; the pits in fig. 17 (var. *rugulata*) are wide apart and roundish; in other specimens (fig. 21) they take a rough reticulate pattern (*retirugata*); and in others (fig. 24) the reticulation is delicate (var. *textilis*), the meshes are open, with thin walls, and become regular and rectangular on the ventral region, where the longitudinal mesh-walls represent the riblets of other specimens.

At first I was inclined to separate figs. 17–20 off from the others as a distinct form (*C. rugulata*); but the gradation to fig. 21 is evident, and Dr. G. S. Brady has suggested that it may be the male form; nevertheless it will be convenient to keep *rugulata* as a varietal name. The pattern of fig. 24 is the same as that of the foregoing, although in detail the reticulation is more like lace-work, the meshes being much finer, and the costulation far more delicate. The last deserves a varietal name, *textilis*.

In figs. 17–20 each pit seems to open inwards in a little tube; and each mesh in figs. 21–23 has two or more of such little perforations.

C. retirugata (type) was found in specimen no. 253 (figs. 21–23), from Hartwell; and no. 364 from Swindon (Prof. Blake).

C. rugulata in four specimens, nos. 256 (figs. 17, 18), 258 (fig. 20), 269 (fig. 19), and 357, all from Hartwell.

C. textilis, also from Hartwell (Barnard's pit), specimen no. 166 (fig. 24), and from Brill.

EXPLANATION OF PLATES VIII. & IX.

(The specimens are figured with the front ends upwards.)

Plate VIII.

Fig.			No. of Specimen.	Magnified (diam.).
1.	*Cypridea punctata* (Forbes), var. *posticalis*, Jones. Carapace, side view	Middle Purbeck; Mewps Bay.	61A, 5	25
2.	—— —— ——. Left valve...........	„ „	61A, 6	25
3.	—— —— ——. Carapace, edge view	„ „	61A, 2	25
4.	*Cypridea punctata* (Forbes). Left valve, inside	Upper Purbeck; Durlston Bay.	34, 13	30
5.	—— —— ——. Right valve, inside	„ „	34, 20	30
6.	*Cypridea punctata* (Forbes), var. *posticalis*, Jones. Right valve	Mid-Purbeck; Ridgway.	382 (XB4/5), 2	20
7.	—— ——, var. *gibbosa* (Forbes). Left valve	„ „	382, 3	20
8.	—— ——, var. *posticalis*, Jones. Left valve	„ „	382, 4	20
9.	*Cypridea Dunkeri*, Jones. Carapace, edge view	Middle Purbeck; Mewps Bay.	61A, 16	25
10.	—— ——. Right valve	„ „	61A, 17	25
11.	*Metacypris Forbesii*, Jones. Left valve	Mid-Purbeck; Ridgway.	382, 8	30
12.	—— ——. Carapace, end view	Middle Purbeck; Mewps Bay.	61, 3	30
13.	—— ——. Left valve (rather verrucose)	„ „	61, 6	30
14.	—— ——, var. *verrucosa*, Jones. Carapace, dorsal aspect	„ „	61, 2	30
15.	—— ——. Carapace, ventral aspect	Mid-Purbeck; Ridgway?	60A, 4	30
16.	—— ——. Right valve, inside	„ „	123A, 3	30
17.	*Cypridea Dunkeri*, Jones. Right valve	„ „	382, 1	25
18.	*Cypridea granulosa* (Sow.), var. *paucigranulata*, Jones. Left valve	Mid-Purbeck; Whitchurch?	229,2	25
19.	—— —— ——. Carapace, ventral view......................................			25
20.	—— —— ——. Carapace, end view			25
21.	—— ——, Right valve, inside	„ „	229,13	25
22.	*Cypridea tuberculata* (Sow.), var. *adjuncta*, Jones. Right valve......	Upper Purbeck; Mewps Bay.	27, 3	25
23.	—— —— ——. Carapace, end view			25
24.	—— —— ——. Dorsal edge of valve			25
25.	*Cypridea ventrosa*, Jones. Left valve, ventral aspect............................	Upper Purbeck; Durlston Bay.	40, 2	25
26.	—— ——. Outside of the same valve			25
27.	*Cyprione Bristovii*, Jones. Left valve	„ „	40, 11	30
28.	—— ——. Inside of right valve......	„ „	40AA, 1	30
29.	—— ——. Inside of left valve	„ „	40AA, 2	30
30.	*Darwinula leguminella* (Forbes). Left valve	Middle Purbeck; Mewps Bay.	61, 21	30
31.	—— ——. Edge view of carapace ...	„ „	61, 17	30
32.	*Cyprione Bristovii*, Jones. Immature form....................................	„ „	27, 11	30

Note.—The small numbers indicate the individual specimen on the slide.

Plate IX.

Fig.		Locality	No. of Specimen.	Magnified (diam.).
1.	*Cypris purbeckensis*, Forbes. Inside of left valve	Lower Purbeck; Vale of Wardour.	230, 6	20
2.	—— ——. Right valve	,, ,,	230, 2	20
3.	—— —— (reniform variety). Left valve	Lower Purbeck; Hartwell.	350, 3	20
4.	—— ——. Edge view of carapace	Lower Purbeck; Vale of Wardour.	230, 1	20
5.	—— ——. Left valve	Lower Purbeck; Whitchurch.	227, 1	20
6.	—— ——. Right valve (thick)	Lower Purbeck; Teffont.	"Cunnington, 3"	20
7.	*Candona bononiensis*, Jones. Right valve	Lower Purbeck; Hartwell.	353, 1	20
8.	—— ——. Edge of valve	,, ,,	353, 2	20
9.	*Candona ansata*, Jones. Left valve, inside	,, ,,	269, 11	30
10.	—— ——. Right valve	Lower Purbeck; South Oving.	363, 3	30
11.	—— ——. Edge view of valve	,, ,,	363, 2	30
12.	—— ——. Left valve	,, ,,	363,4	30
13.	*Cythere transiens*, Jones. Left valve, inside	Lower Purbeck; Swindon.	964, 8	40
14.	—— ——. Right valve, inside	,, ,,	364, 9	40
15.	—— ——. Carapace ventral view	,, ,,	364, 7	40
16.	—— ——. Left valve	,, ,,	364, 2	40
17.	*Cythere retirugata*, Jones, var. *rugulata*, Jones. Left valve	Lower Purbeck; Hartwell.	256, 2	30
18.	—— ——. Left valve, inside	,, ,,	256, 4	30
19.	—— ——. Carapace, ventral view	,, ,,	269, 5	30
20.	—— ——. Right valve, inside	,, ,,	258, 6	30
21.	*Cythere retirugata*, Jones. Left valve	,, ,,	253, 8	30
22.	—— ——. Carapace, ventral aspect	,, ,,	253, 2	30
23.	—— ——. Right valve, inside	,, ,,	253, 11	30
24.	—— ——, var. *textilis*, Jones. Right valve	,, ,,	166, 1	30

Discussion.

Prof. Blake thought that the Purbeck beds of Swindon were contemporaneous with the Portlandian further south, and that this view was confirmed by the mingling of marine and freshwater forms.

Dr. Hinde pointed out that the name of *Darwinella* had been already employed by Fritz Müller for a genus of horny sponges.

Mr. Whitaker asked for further information as to the species of Ostracoda being characteristic of the several divisions of the Purbeck.

Dr. Woodward pointed out the necessity of indicating the dorsal and ventral aspects of all the forms, so as to facilitate their com-

parison with living forms. He regretted the number of names which had to be coined for the subgenera of *Cypris*.

The Author said that *Darwinella* was a genus founded by Brady, and he regretted if that author had been forestalled. It is difficult at times to distinguish the ends in fossil Ostracoda, and it is not always possible to distinguish between the dorsal and ventral sides; but in these Purbeck forms there is no doubt or difficulty. With respect to Swindon, the study of these fossils seems to confirm the views of the late Mr. Charles Moore and Prof. Morris.

30. *On the* Tertiary *and* Older Peridotites *of* Scotland. By Prof. John W. Judd, F.R.S., Sec. G.S. (Read February 11, 1885.)

[Plates X.–XIII.]

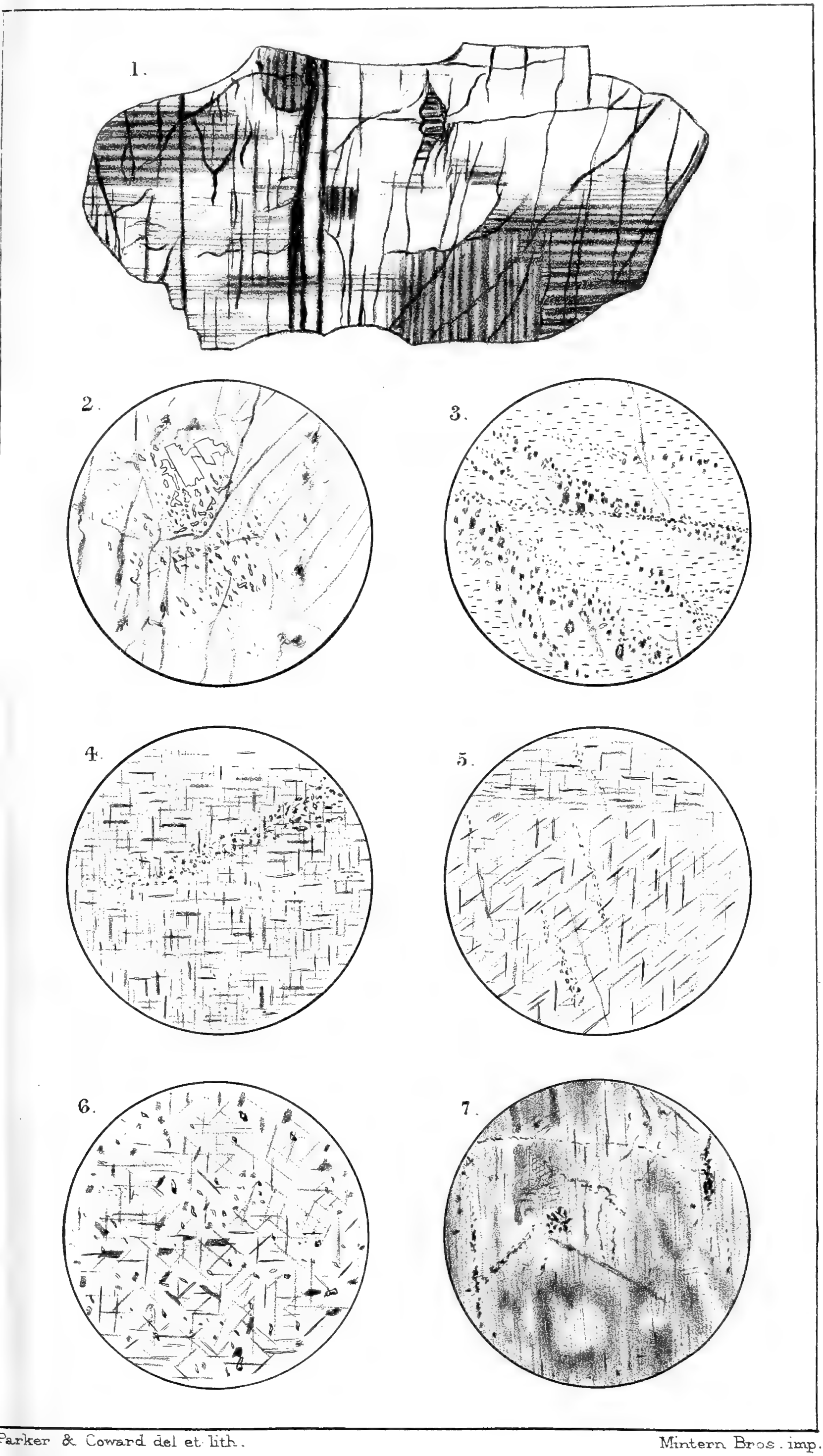
Introduction.

Those rocks which contain an excessive proportion of the bases, especially magnesia and ferrous oxide, and are therefore composed largely of unisilicates, may be conveniently classed as *ultra-basic* rocks. Such rocks constitute a small but highly interesting group, which is characterized as follows:—They have a very low percentage of silica, ranging generally from 35 to 45, with a high specific gravity, varying from 3 to 4; while the ferro-magnesian silicates, olivine and enstatite, enter largely into their constitution. Felspar is often altogether absent from these rocks, and, when present, appears to be always represented by the basic species anorthite, or one approaching in composition to that type.

Many of these ultra-basic rocks may be very conveniently grouped, as Professor Rosenbusch proposes, under the name of "peridotites;" rocks, that is, in which the unisilicate, olivine, forms the prevailing constituent.

There are other ultra-basic rocks, however, which contain a considerable proportion of the bisilicates, and these form a link between true peridotites and the ordinary basic rocks. Among these may be noticed the picrites, in which olivine is united with a considerable proportion of augite, hornblende, or biotite, anorthite-augite rock (eucrite) *, anorthite-hornblende rock (corsite), and anorthite-olivine rock (troctolite or forellenstein).

[* It is possible that teschenite must be grouped with those rocks which lie on the border line between the basic and the ultra-basic groups. See Rohrbach, Tschermak's Min. und Petr. Mittheil. vol. vii. (1885) p. 1.]



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SECONDARY STRUCTURES IN FELSPARS.

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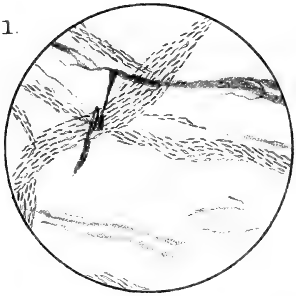

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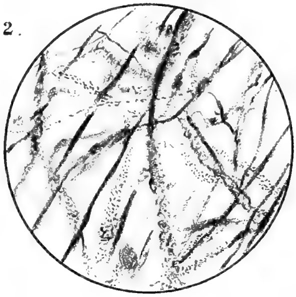

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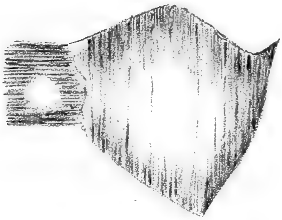

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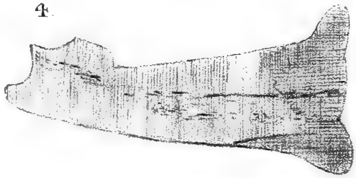

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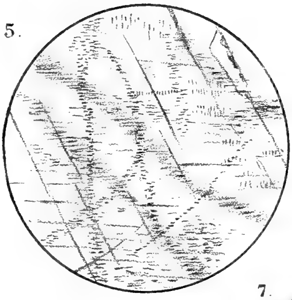

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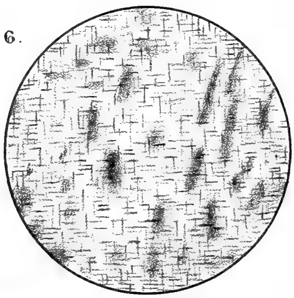

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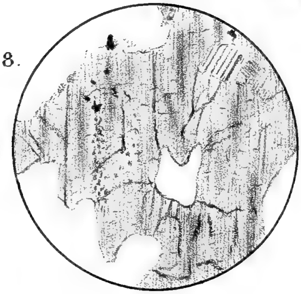

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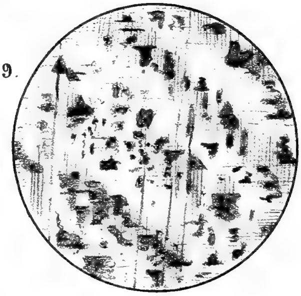
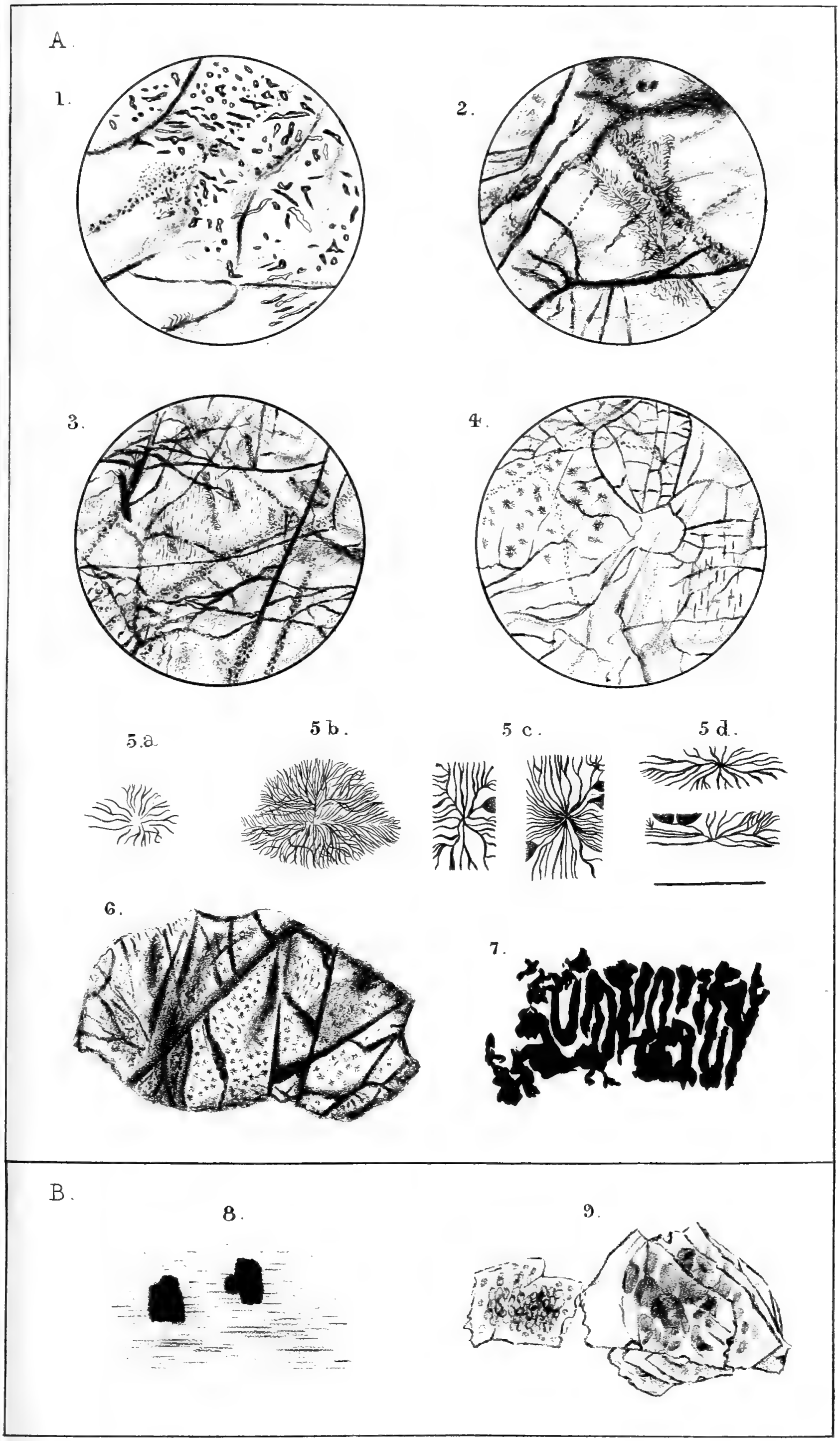


Parker & Coward del et lith. Mintern Bros. imp.

SECONDARY STRUCTURES IN PYROXENES.



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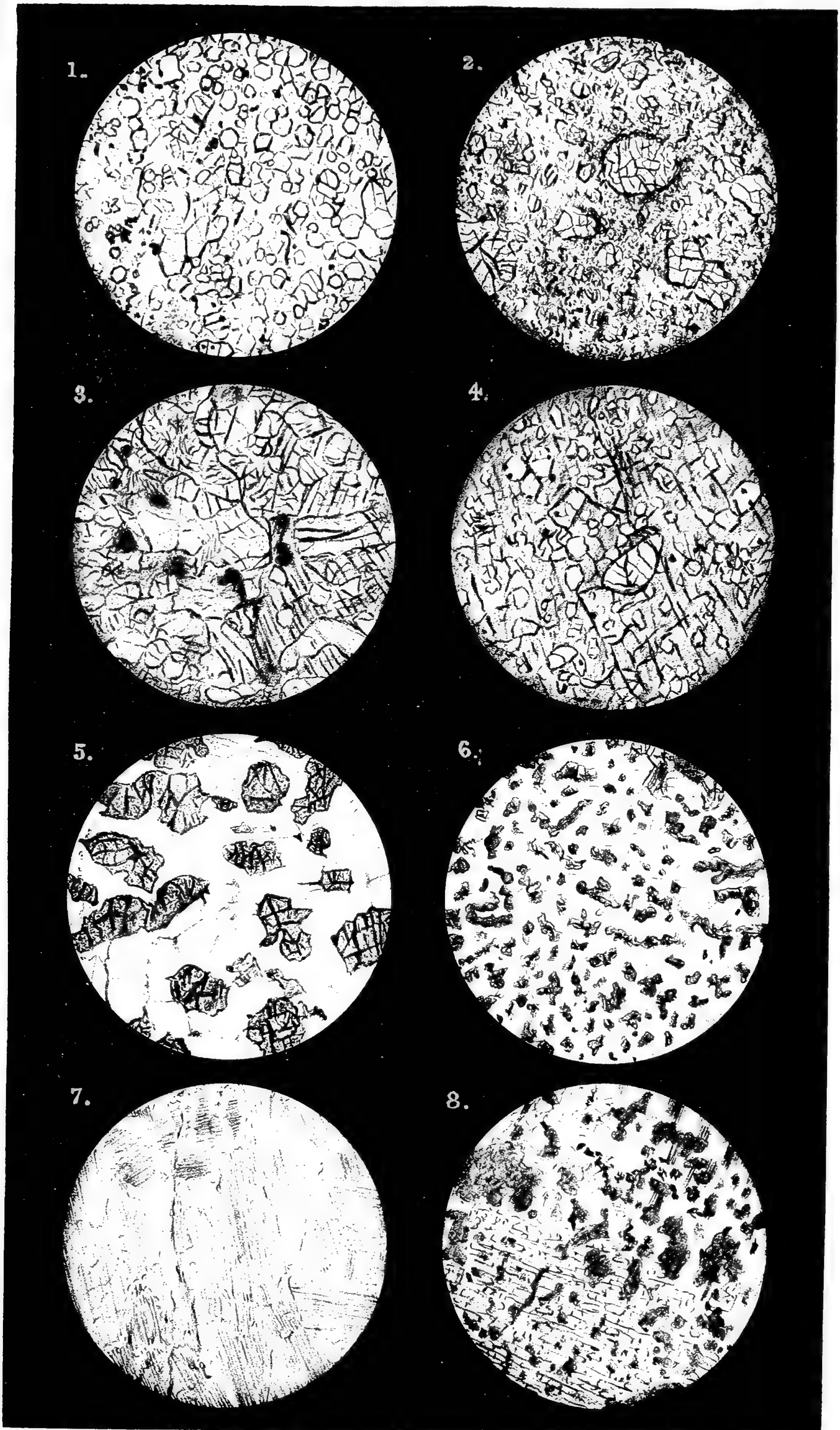
SECONDARY STRUCTURES IN (A) OLIVINE, (B) BIOTITE.



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VARIETIES OF SCOTTISH ULTRA-BASIC ROCKS.

The peridotites and their allies are of especial interest to geologists on four different grounds:—*First*, their mode of occurrence has been thought to be suggestive of their having come from deeply-seated portions of the earth's crust, and they have therefore been supposed to afford some indications concerning the constitution of the earth's central mass. *Secondly*, they are the source from which many, if not, indeed, all, of those very interesting rocks the serpentines have been derived by hydration. *Thirdly*, in rocks of this class the remarkable mineral, diamond, has been found *in situ*. And *fourthly*, they exhibit many striking points of resemblance with those wonderful "extra-terrestrial rocks"—the meteorites.

The peridotites which have, up to the present time, been described appear to be *plutonic* rocks, forming either the whole or portions of intrusive masses. The enclosures in basalt and the "olivine-bombs" contained in basaltic tuffs constitute apparent—but probably only apparent—exceptions to this rule, for they would seem to have been brought from below entangled in the lavas and scoriæ with which they are associated. Professor Rosenbusch is inclined to regard the "limburgites" as analogous to the peridotites, and some of these rocks certainly have an ultimate chemical composition suggestive of an alliance with the ultra-basic types. But the majority of the limburgites would seem to be, like the magma-basalts of Bořický and Möhl, rocks in which consolidation has taken place before the individualization by crystalline action of the more acid constituents which form the felspar, nepheline, or leucite.

The true peridotites have been usually regarded as belonging to the older geological periods; by some authors, indeed, they have been stated to be absolutely characteristic of the Pre-Tertiary epochs. In Scotland, however, we find great masses of undoubted peridotites, exhibiting all the essential features of their older analogues, but associated in the most intimate manner with the intrusive rock-masses which I have, on a previous occasion, shown to be the central cores of great volcanoes built up by successive outbursts during the earlier Tertiary periods.

But it is not alone on account of their younger geological age that the peridotites and allied rocks of the Western Isles of Scotland are of such extreme interest to geologists. Owing probably to their comparatively recent origin, the minerals of which these rocks are composed are in a remarkably fresh and unweathered condition, supplying us, as I hope to show in this paper, with admirable facilities for studying certain questions concerning their origin and mode of development. Examined from this point of view, the Tertiary Peridotites of Scotland furnish us with valuable suggestions for the solution of many problems concerning the older rocks of the same class, and their altered representatives, the serpentines, not only in Scotland, but in other parts of the globe. They are also important from their grand development in this district—forming, as we shall see that they do, a considerable portion of great mountain-masses, which cover considerable areas.

Part I.

The Tertiary Peridotites and Allied Rocks.

§ 1. Relations of these Rocks to the other Eruptive Masses of the Western Isles of Scotland.

More than ten years ago I was enabled, by a careful study of the Western Isles of Scotland, to demonstrate that the eruptive masses of granite and gabbro of that area constitute the denuded cores or basal wrecks of great volcanoes built up during the earlier Tertiary periods *. As Professor Zirkel had shortly before visited the district for the purpose of collecting specimens of the leading types of rocks in it, and had given a detailed account of their microscopical characters †, I made the petrographical determinations of that excellent observer the basis of my field-work, reserving to a future occasion a full account of the minute structure of the very large series of typical rocks which I collected during my field-work extending over several years, as well as in subsequent visits to the district. In fulfilment of the engagement I then made, I have as yet only been able to deal with the basaltic glasses, in a paper in preparing which I had the cooperation of my friend Mr. Cole ‡, and I now lay before the Society a second instalment of the task.

The ultra-basic rocks of the Western Isles of Scotland form subordinate portions of several of the great basic eruptive masses of the Western Isles of Scotland. They are especially developed in the Isle of Rum and in the Shiant Isles. By Macculloch, to whose careful studies we owe so much of our knowledge of the district where they occur, the difference of these rocks from those with which they are associated was clearly recognized, though their true nature was to some extent misunderstood. As we shall hereafter show, the olivine which forms such an important constituent in most of these rocks has undergone a curious modification, by which it is caused to assume a darker colour than is usual in the mineral. In consequence of this change the olivine in many of these rocks appears to the naked eye so similar to the associated augite, that it is not surprising to find Macculloch confounding the two minerals and supposing the rocks to be almost wholly composed of augite. It was in this way that he was led to give them the name of "augite-rock" §. That no subsequent observers have noticed these remarkable rocks is probably accounted for by the fact that the Isle of Rum is seldom visited, while the Shiant Isles are not only almost uninhabited, but are very difficult of access.

The basic eruptive rocks, with which the ultra-basic ones are so intimately associated, fall into the two classes of gabbros and dolerites.

* Quart. Journ. Geol. Soc. vol. xxx. (1874) pp. 220–302.

† Zeitschr. d. deutsch. geolog. Gesell. vol. xxiii. (1871) p. 1.

‡ Quart. Journ. Geol. Soc. vol. xxxix. (1883) p. 444.

§ A Description of the Western Isles of Scotland, &c., by John Macculloch, M.D. (1819), vol. i. pp. 436, 485, &c.

The gabbros, as Zirkel so well showed *, belong for the most part to the class of the olivine-gabbros, the olivine in these rocks, however, being frequently so curiously obscured, as to be easily overlooked.

By other writers these rocks have been called hypersthene-rock †, hypersthenite or hyperite ‡, hyperitic diabase §, labrador-syenite ||, and norite ¶.

The main cause of the conflict of opinion concerning the nature of this rock and the name by which it should be called was the difficulty found in determining its conspicuous pyroxenic constituent. As we shall show hereafter, Zirkel was undoubtedly right in referring this pyroxene to diallage, the foliated form of augite **. At the same time it must be borne in mind that the various forms of enstatite, and among them true hypersthene, are also frequently present, and sometimes in such proportions as to entitle the rock to be called an "olivine-enstatite-gabbro."

It is a surprising circumstance that some authors have regarded the rock in question as being of metamorphic origin and of Archæan age. The only possible ground for such a conclusion which I can conceive of is that the rocks present certain parallel division-planes, and are built up of the same minerals as some supposed Laurentian rocks. As for the parallel division-planes they are certainly nothing but the great concentric joints which are so often found traversing both gabbros and granites; while, as I have elsewhere shown, the connexion of these rocks with the Post-Tertiary basalts is unmistakable.

As, however, the supposed metamorphic origin and Archæan age of the gabbros of the Cuchullin Hills of Skye has not only been taken for granted, but has been made the basis of curious theoretical speculations, it may be well to trace the idea to its original source.

The first who broached these notions appears to have been Dr. A. Geikie ††, before whom, so far as I am aware, no one had questioned the reference made by Macculloch of these rocks to the

* Zeitschr. d. deutsch. geol. Gesell. xxiii. (1871) p. 58. In 1878, Prof. von Lasaulx gave an interesting account of the microscopical characters of the similar rocks of the Carlingford Mountains, which form, as I have shown, a portion of the same great Tertiary series of outbursts. (Tschermak, Min. u. Petr. Mitth. 1878, p. 426.) His results are in close agreement with those of Prof. Zirkel.

† Macculloch, 'Western Isles,' vol. i. p. 385; Geikie, 'Scenery and Geology of Scotland' (1865), p. 210.

‡ Heddle, Trans. Roy. Soc. Edin. vol. xxviii. (1879) p. 478.

§ Heddle, *loc. cit.* vol. xxviii. (1879) p. 252.

|| Haughton, Dubl. Quart. Journ. Sc. vol. v. (1865) p. 94.

¶ Sterry Hunt, Chem. & Geol. Essays, 2nd ed. (1879) p. 281.

** Dr. Heddle has arrived at the startling conclusion that not only is diallage never found in these rocks, but that in Scotland this mineral occurs only in metamorphic rocks! (See Trans. Roy. Soc. Edinb. vol. xxviii. (1879), p. 477 footnote.)

†† Trans. Roy. Soc. Edinb. vol. xxi. (1861) p. 633; also 'Scenery and Geology of Scotland' (1865), p. 210, footnote, and Murchison and Geikie's Geological Map of Scotland, 1st edition, 1865.

igneous group. In 1865, Dr. Haughton paid a brief visit to Skye, and on his return expressed the same opinion concerning the origin and age of these rocks *. That the Archæan age and metamorphic origin of the rocks in question is no longer maintained by the first-mentioned author, is evident from several of his later writings †; nevertheless, the erroneous identification has been adopted by Dr. Sterry Hunt ‡, who makes a strong point of it as supporting his views concerning the chronological classification of rocks, based on their mineralogical characters. It is but just, however, to this author to conclude that his acquaintance with the rocks of Skye is probably limited to hand-specimens.

The gabbros of the Inner Hebrides present, as I have already shown, all the distinctive characteristics of igneous eruptive masses. They are, as a matter of fact, remarkably free from all traces of the foliated structure which is sometimes found superinduced in igneous rocks of greater geological antiquity. In their general relations, as well as in their structure, they present the most remarkable analogy with the granites, of which they are clearly the representatives in the basic series of rocks. Thus they form mountainous masses intersected in all directions by the so-called "contemporaneous" or "segregation" veins, and are sometimes studded with enclosures composed of the same minerals as the rock itself, but in different proportions. These gabbro-masses become finer-grained and less perfectly crystalline towards their edges, and they give off innumerable veins into the surrounding rocks, while the most striking effects of contact-metamorphism are seen in stratified materials lying in juxtaposition with them.

The dolerites of the Western Isles of Scotland form smaller eruptive masses, and also great intrusive sheets which are not only seen to be connected with the larger gabbro-intrusions, but graduate into them in the most insensible manner. Some of the thickest of the lava-flows are also dolerites, undistinguishable in their characters from the intrusive masses.

Locally, both gabbros and dolerites are found passing into peridotites by the gradual disappearance of the felspar and the increase in quantity of the olivine. In this way the felspathic rocks are seen graduating insensibly into the non-felspathic forms, and these latter, in the island of Rum, cover vast areas and form the bulk of mountain-masses thousands of feet in height. It is noteworthy that the peridotites make their appearance not only in the deepest valleys of Rum, but also on the top of Halival and other mountains in the island which are between 2000 and 3000 feet high.

But there is another and very interesting mode of association of the peridotites with the gabbros and dolerites, which is especially worthy of notice. The peridotites are often found in segregation-nodules in the gabbros, and occasionally segregation-nodules of gabbro are found in the peridotites, the phenomena being strikingly

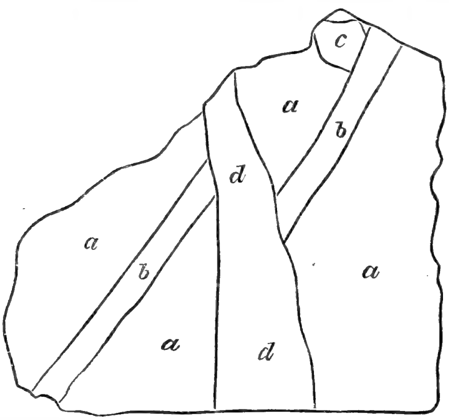
* Dublin Quart. Journ. Sci. vol. v. (1865), p. 94.

† A. Geikie, 'Text-Book of Geology' (1882), p. 150.

‡ Sterry Hunt, 'Chemical and Geological Essays,' 2nd edition (1879), p. 279.

parallel to those displayed by the granites, and so well described by Mr. J. A. Phillips, F.R.S.* Still more frequently the so-called "segregation" veins of peridotite are seen traversing the gabbro, and similar veins of gabbro are found intersecting the peridotite masses. Not unfrequently, too, such veins are found composed of picrite, eucrite, or troctolite. That these so-called "segregation" or "contemporaneous" veins have been formed at different times is shown by the fact that one vein is frequently intersected and shifted in position by another. A beautiful example of this kind is illustrated in the annexed diagram.

Intersecting Veins of Gabbro and Dunite in Olivine Rock, $\frac{1}{3}$ nat. size



a. Olivine rock (dunite).
b. Olivine-gabbro vein traversing the same.
c. Segregation-nodule of felspathic rock.
d. Porphyritic dunite intersecting and shifting the gabbro-vein.

As is not uncommonly the case with such veins, the minerals in them have sometimes a special arrangement of their own. Thus in the case figured above, the olivine-gabbro-vein (*b*) has its felspar grouped principally along the sides, and the augite and olivine in the centre.

The relations of the gabbros and peridotites in the Western Isles of Scotland seem to indicate that in the heart of these old volcanoes the felspar, olivine, and augite tended to segregate in certain cases into masses of various dimensions; and that these masses were, after consolidation, fissured again and again, the fissures being injected by different portions of the magma, which were still in a more or less plastic condition.

The very close association of peridotites with gabbros is not by any means peculiar to the district we are describing. In the Hartz, in Nassau, in Baden, in Silesia, and in many other districts a similar association of rocks prevails; and in many, if not all of these cases,

* Quart. Journ. Geol. Soc. vol. xxxvi. (1880) p. 1.

the pyroxenes and olivines of the felspathic and the non-felspathic rocks exhibit the most striking resemblances.

To the similar relations between the altered peridotites (or serpentines) and gabbros, which have been so frequently remarked upon by Prof. Bonney * and others, I need do no more than make a passing reference.

The constant association of serpentines, which are altered peridotites, with gabbros appears to have led to the supposition, a highly improbable one, that the latter rocks can be changed into serpentine. The fact that the felspathic rocks graduate so constantly into the non-felspathic will fully account for the association of the hydrated representatives of the latter class with the more or less altered representatives of the former without the necessity of our having recourse to the violent hypothesis referred to.

§ 2. Microscopic Structure of the Rocks.

The larger intrusive masses of basic composition in the Inner Hebrides are all perfectly *holocrystalline,* and show no vestige of a glassy basis or ground-mass. Nevertheless some very interesting and distinctive structures are seen to be exhibited by them, when they are studied in thin sections, under the microscope.

The structure usually displayed by the gabbros may be defined as *granitic*, that is to say, they are built up of crystals, the development of the outward forms of which has been to a great extent prevented by the growth in juxtaposition with them of other crystals. We may perhaps conclude that in these rocks the separation in the magma of the several minerals, felspar, augite, and olivine, took place almost simultaneously.

Occasionally, however, the minerals of the gabbros have a tendency to the formation of more or less rounded grains, and an approach to the *granulitic* structure is exhibited.

The gabbros vary greatly in the coarseness of their grain. In Skye and Ardnamurchan, we find rocks made up of crystals an inch or more in length, and every gradation is seen from these coarse-grained rocks down to those in which the crystals are extremely minute.

The dolerites, which are, as a general rule, finer-grained rocks, exhibit two very interesting types of structure, which seem to be worthy of careful study.

For the first of these I propose, following M. Michel Lévy, to employ the term *ophitic* structure, from its having been first noticed in connexion with those interesting rocks, the ophites of the Pyrenees †. Dr. A. Geikie has also described it as occurring in the intrusive rocks of Carboniferous age in the central valley of Scotland ‡. In this class of rock the augite is found crystallized in large patches,

* Quart. Journ. Geol. Soc. vol. xxxii. (1877) p. 915, vol. xxxiv. (1879) p. 783; Geol. Mag. dec. ii. vol. vi. (1879) p. 370.

† Bull. Soc. Geol. d. Fr. 3me sér. tom. vi. (1877) p. 156.

‡ Trans. Roy. Soc. Edinb. vol. xxix. (1880) p. 495.

which enclose well-formed crystals of felspar. The crystalline continuity of these large patches of augite is shown by the broad cleavage-fractures, which cause the rock to present a number of brilliant faces reflecting light. Under the microscope the same fact becomes still more obvious by the persistence of the cleavage-cracks, and by the same optical relations being exhibited over considerable areas, when the sections are viewed by polarized light.

Nowhere is this beautiful ophitic structure more admirably displayed than in the Shiant Isles, but in a less perfect condition it is seen in the later intrusive masses of Sarsta Beinn in Mull*, and many other localities. While, on the one hand, the gabbros not unfrequently exhibit some indications of an approximation to this structure, it is also displayed in a far less perfect condition (semi-ophitic structure) in some of the basalts. The careful examination of these rocks with the microscope fully bears out my original conclusion, derived from studies in the field, that the most perfect transitions occur from gabbros through dolerites and basalts to basalt-glass.

The other structure presented by the dolerites I have ventured to designate as the *porphyro-granulitic structure.* The base of these dolerites is composed of a mixture of lath-shaped felspars, and small irregular grains of augite, and through this base large porphyritic crystals of felspar and large grains of olivine are distributed in greater or less abundance. A very excellent example of this structure is exhibited by the rock at Ru Geur in Skye †.

Some of the granitic gabbros exhibit a distinct approach to the ophitic structure in the arrangement of their crystals, while the granulitic gabbros graduate insensibly into the porphyro-granulitic dolerites. Both the ophitic and the granulitic dolerites are found in turn passing insensibly into basalts by the appearance of a more or less glassy base between the crystals.

I propose to discuss the origin of these structures and the manner in which they shade insensibly into one another, and also into the structures characteristic of the basalts, in a subsequent paper devoted to the description of the whole of the basic rocks of the Western Isles of Scotland. It was necessary, however, to refer to the subject here, as the peridotites in every case exhibit a structure analogous to that of the gabbro or dolerite with which they are associated. Thus a gabbro, by the disappearance of its felspar, is seen passing into a peridotite of granitic structure; and an ophitic dolerite, in the same way, graduates into a peridotite with ophitic structure. In Pl. XIII. fig. 2 exhibits an example of the porphyro-granulitic structure, figs. 5 & 6 of the granulitic, figs. 4 & 8 of the ophitic, and fig. 7 of the granitic structures, as exhibited in rocks of the ultra-basic class.

* Quart. Journ. Geol. Soc. vol. xxx. (1875) p. 264–266.

† *Ibid.* vol. xxxiii. (1878) p. 692. This dolerite, in its platy structure, so closely resembles a phonolite, that from my examination in the field I was erroneously led to class it with those rocks.

§ 3. Minerals of which the Rocks are built up.

As the species of minerals, and the different varieties of those species, are the same in the peridotites as in the dolerites and gabbros of the Inner Hebrides, it will be necessary to give a detailed account of them in the present memoir, the discussion serving not only for the ultrabasic, but also for the basic rocks, which will be described in a subsequent communication.

Much confusion has been introduced into petrographical literature, in consequence of all the characters presented by minerals being treated as if they had precisely the same significance. But while some of the characters of the rock-forming minerals are original and essential, others are, as certainly, secondary and accidental. Moreover, the minerals, since their first crystallization, may have undergone several series of changes totally dissimilar in kind, and resulting from causes altogether different. It therefore becomes necessary to distinguish not only the secondary from the original characters, but to assign each of the secondary characters to its proper cause. This is the task which I have endeavoured to perform in the case of each of the minerals which go to build up the rocks now under discussion.

It will, I think, conduce to clearness, if I indicate at the outset what appear to have been the original peculiarities of the several minerals in these rocks, and show what were their physical properties and chemical composition in their *unaltered* condition. I shall then proceed to describe the changes which, in certain situations, they are found to have undergone, and to discuss the cause of these changes.

The Felspars.—Plagioclase felspar, which constitutes one half, or even more than one half, of some of the gabbros, and is equally abundant in the eucrites and in the troctolites, becomes so rare in many of the peridotites that it can no longer be regarded as an essential constituent of them. But, as already stated, we find every possible gradation from the most highly felspathic rocks to others in which the felspar entirely disappears.

The crystals of the felspars vary greatly in size; sometimes the gabbros are fine-grained, almost compact rocks; at other times they are built up of crystals of great size, up to one or two inches in length. As a rule, the most coarsely crystalline varieties are found in the centre of the largest intrusive masses, like those of Skye and Ardnamurchan. In the case of these large masses, the tint and play of colours in some of the felspar-crystals suggest that they are labradorite, and they were recognized as such by Macculloch as long ago as 1819 *.

The tests of specific gravity, of fusibility, of the flame-reaction of Szabó, and of the extinction-angle, as suggested by Lévy and Fouqué, all point to the conclusion that these felspars are, in chemical composition, intermediate between labradorite and anorthite, in some cases approaching the former, in other cases the latter species. Such

* A Description of the Western Isles of Scotland, vol. i. p. 413.

analyses as have been made of these felspars entirely support this conclusion. These analyses are as follows:—

Felspars of Gabbros of the Western Isles, and the North of Ireland.

	I.	II.	III.	IV.
Silica	53·60	50·811	49·155	45·87
Alumina	29·88	29·480	29·620	34·73
Ferric oxide	0·22	0·252	1·152	
Lime	11·02	12·690	15·309	17·10
Magnesia	0·07	0·124	0·911	1·55
Soda	4·92	3·922	2·914	
Potash	0·80	0·552	0·695	
Water	0·48	2·481	0·730	
	100·99	100·312	100·486	99·25

I. Is from Loch Scavaig, Skye. Analysis by Dr. Haughton, Dubl. Quart. Journ. Sci. vol. v. (1865) p. 94.

(The iron has been calculated as ferric oxide, so as to correspond with the other analyses.)

II. Is also from Loch Scavaig, Skye. Analysis by Dr. Heddle of specimen, consisting of a large crystal, bluish grey in colour, and finely striated: specific gravity 2·715. Trans. Roy. Soc. Edinb. vol. xxviii. (1879) p. 253.

III. Is from Hart o' Corry in the Cuchullin Hills, Skye. Analysis by Dr. Heddle of a specimen of an unstriated variety occurring in granules. Trans. Roy. Soc. Edinb. vol. xxviii. (1879) p. 253.

IV. Felspar from the Carlingford Mountain, County Down: by Dr. Haughton. Phil. Mag. ser. iv. vol. xix. (1860) p. 13.

While I. agrees very fairly with the analyses of typical labradorites, III. approaches very closely in composition to anorthite, and IV. is a perfectly typical anorthite; in II. the proportions of lime and soda are intermediate between those characterizing the two species.

The presence of water, ferric oxide, and magnesia, indicates that the felspar of these rocks has undergone a certain amount of alteration, the nature and cause of which will be discussed in the sequel.

When studied by the aid of the microscope, these felspars but rarely, so far as I have observed, exhibit examples of zoned structure. Occasionally, however, we find evidence that the crystals are built up of intergrowths of two different species of felspar—the well-known "perthite-structure" being produced. In the great majority of cases, however, the optical uniformity of the crystals, when viewed by polarized light, indicates that we are dealing with a homogeneous substance, with definite optical constants, a result in harmony with those obtained by Max Schuster *.

Some of the felspars in these rocks exhibit in the most striking manner the twin lamellæ, which become very conspicuous when the sections are viewed with the polariscope. But while certain crystals

* Tschermak's Min. Petr. Mitth. vol. iii. (1880) p. 117.

display this structure in its most complete development, others are quite destitute of it, and others, again, exhibit it in irregular and interrupted portions of their mass.

At one time the presence of lamellar twinning was regarded by petrographers as an essential characteristic of the plagioclase felspars, and when untwinned or simply-twinned felspar-crystals were met with, even in the most basic rocks, they were referred to orthoclase. But this view has now been generally abandoned, and the late Dr. G. Hawes * has demonstrated that the most typical oligoclases, andesines, labradorites, and anorthites sometimes present no trace whatever of lamellar twinning.

Much new light has been thrown by recent researches on the manner in which twin lamellæ may be produced in crystals; and the results of these investigations are worthy of the most careful consideration by the petrographer and geologist.

As long ago as 1859, it was shown by Pfaff that remarkable changes are induced in the optical properties of calcite when its crystals are subjected to pressure †; and in 1867 Prof. E. Reusch demonstrated that by pressure applied in certain directions to these crystals a definite lamellar twinning could be developed in them ‡. In 1879 Baumhauer showed that the pressure necessary to bring about this twin structure could be applied by simply forcing the edge of a knife-blade in a certain direction into the crystal §, and this conclusion was confirmed by the observations of Brezina ‖.

Now calcite crystals, when freely developed, may attain the largest dimensions without betraying any trace of this lamellar twinning, as is seen in the case of ordinary Iceland-spar. But the great majority of rock-forming calcite-crystals, even when of the smallest size, like those occurring in crystalline limestones and dolomites, for instance, exhibit this lamellar twinning in the most striking manner.

Similar lamellar twinning is exhibited by many rock-forming minerals, such as leucite, garnet, boracite, &c., and has led to many speculations concerning the possibility of these crystals being regarded, not as the simple forms to which they were first referred, but as examples of very complicated structures built up by polysynthetic twinning and belonging to a lower order of symmetry.

But certain recent investigations have thrown a new and unexpected light on this most interesting question. Mallard has shown that boracite loses its twin lamellæ when the crystals are heated to the temperature at which they were originally formed ¶. Merian has proved that tridymite becomes optically hexagonal at high

* Proc. National Mus. 1881, pp. 134–136. See Smithson. Miscell. Collect. vol. xxii.

† Pogg. Ann. vol. cvii. (1859) pp. 333–338.

‡ Pogg. Ann. vol. cxxxii. (1867); ibid. cxli. (1872); also Proc. Roy. Soc. Edinb. vol. vi. (1869) p. 136.

§ Zeitschr. Kryst. vol. iii. (1879) p. 588.

‖ *Ibid.* vol. iv. (1880) p. 518.

¶ Bull. Soc. Min. de France, vol. v. (1882) p. 144.

temperatures *; and, finally, Klein has demonstrated that leucite loses its twin lamellæ, and exhibits the isotropism of cubic crystals at a very high temperature †.

The conclusion to which all these interesting results point is, that the properties of a crystal formed at any given temperature may be greatly modified when that temperature is altered. Thus leucite, while contracting in cooling from the temperature at which it was originally formed, becomes subjected to internal stresses and strains, resulting in lamellar twinning, and even in that alteration of the angular measures of the crystal so long ago pointed out by Vom Rath.

Such being the case, the question which cannot fail to present itself to petrographers is: May not the twin-lamellæ of the plagioclase felspars, like the similar structure in calcite, be not an original and necessary character of the crystals, but one developed in them by pressure or strain?

There are not a few facts which support the hypothesis we have just enunciated. Lamellar twinning is often altogether absent, as we have already seen, in plagioclase felspars; and in the case of the rocks we are now studying, such untwinned plagioclase crystals are especially found in certain veins. In other cases the lamellar twinning is found affecting certain portions of the crystal only, and in the most conspicuous manner. The twin-lamellæ, too, often stop suddenly, or are replaced by narrower and more numerous, or broader and less numerous ones, as is the case with lamellæ artificially produced in calcite. Like the twin-lamellæ in the rock-forming calcite also, those of plagioclase-felspar are sometimes bent in the most remarkable manner. Sometimes the same crystal is found exhibiting two series of lamellar twinnings intersecting one another, as is also the case with calcite. Perhaps the most striking and significant circumstance of all is that where a felspar-crystal is seen to be bent or compressed between other crystals in a rock, the part of the crystal so affected will be traversed by twin-lamellæ, from which other parts of the crystal may be altogether free ‡.

That the tendency to that peculiar disposition of molecules which constitutes lamellar twinning must exist from the first both in calcite and in plagioclase felspars is, of course, freely admitted; but the rearrangement of these molecules in obedience to certain laws seems to be *determined* by the application to them of external mechanical forces. In great, slowly-cooling masses of rock, like those in the centre of volcanic cones, composed of minerals having different coefficients of expansion, not only in different crystals but along different directions in the same crystal, we have forces at work competent to produce those strains and stresses which have been proved to be capable of inducing such a rearrangement of the

* Neues Jahrb. für Min. &c. 1884, i. p. 193.

† Nachrichten der Kön. Ges. d. Wiss. Göttingen, May 1884.

‡ Admirable illustrations of some of these appearances will be found in Cohen's 'Sammlung von Mikrophotographien zur Veranschaulichung der mikroskopischen Structur von Mineralien und Gesteinen,' taf. xxx. 2, 3, lxxv. 1, 2, 4. See also xxxi. 1, 4, and xxx. 4.

molecules; and all the appearances presented by the lamellar twinning of these felspars seem to me to be much more in harmony with the view that it is so induced than with the supposition that the structure is an original one.

With respect to the period at which these twin-lamellæ were developed in the crystals of plagioclase felspar, there is every reason to believe that during the cooling-down of the crystals from the high temperature at which they were developed, many such structures would arise; for they are found alike in the felspars of artificially-formed rocks and in those of drusy cavities and open veins. But the more carefully the positions and relations of these twin-lamellæ are studied, the more clearly does it become apparent that external causes, such as the pressure of adjoining crystals and the other accidents to which they have been subjected since their first formation, have played no inconsiderable part in bringing about the final result. In Pl. X. fig. 1, a crystal of felspar is represented, which admirably illustrates these conclusions.

[At the time when this paper was read I was not aware of the important series of experiments which had been carried on by Herr Förstner, and which are described in the Zeitschr. für Krystall. &c., vol. ix. (1884) p. 333. Förstner took plates of the untwinned plagioclase felspar of the rock from Pantellaria which he has described, and by heating them to various temperatures and cooling them again, he succeeded in developing the twin-lamellæ, and even in producing reentering angles on the edges of the plates similar to those which have been artificially produced in fragments of calcite. These experiments prove conclusively that the twin-lamellæ of plagioclase felspar *can be* developed by the application of mechanical force; and that they are constantly so produced in rock-masses, I have in the foregoing pages given reasons for concluding.]

The Pyroxenes.—There has been a very great conflict of opinion concerning the pyroxenes in the gabbros of the Western Isles of Scotland. Macculloch, while rightly identifying the pyroxene in the great mass of these rocks as augite, stated that hypersthene occurs in the Cuchullin Hills of Skye, in Ardnamurchan, and at one point in the island of Rum *. In these statements he was perfectly correct, but in going farther and describing the rock-masses of the Cuchullin Hills and the western parts of Ardnamurchan as hypersthene-rock, Macculloch fell into an error; for in all these rocks, as was pointed out by Zirkel, the predominant pyroxene is diallage, the foliated form of augite, and not hypersthene. We shall show, however, that augite frequently occurs in these rocks in an altered form, which so curiously mimics the colour, lustre, and general appearance of hypersthene that Macculloch's error was a very natural and pardonable one.

Descloiseaux's researches in 1862 showed that the pyroxenes can be divided into two groups, those in which lime is the predominant base, crystallizing in the monoclinic system—the augites—and those

* A Description of the Western Isles of Scotland, vol. i. pp. 385, 390, 413, 503.

in which magnesia is the principal base, crystallizing in the rhombic system—the enstatites. Both of these classes of pyroxene are represented in the basic rocks of the Western Isles of Scotland; but the augites occur by far the most abundantly.

In both the monoclinic and the rhombic pyroxenes we find a series of varieties differing from one another by the proportion of iron which they contain. The highly ferriferous varieties of both minerals occur, however, most commonly in these rocks.

The augites are occasionally represented by varieties which appear bright green by reflected, and pale green by transmitted light. Such forms, which resemble diopside, occur at several points in the island of Mull, especially in Glen More, and at other points near Carsaig. In the island of Rum, on the flanks and summits of the mountains of Halival, Haiskeval, and Tralival, this green augite is remarkable for the absence of regular crystalline forms and of cleavage-cracks; it often occurs in more or less rounded and irregular grains resembling coccolite.

This green augite (diopside) of Halival, which was mistaken by Jameson for pitchstone, has been analyzed by Dr. Heddle*, and his analysis gives us a good idea of the composition of the least ferriferous varieties of the augite of these rocks. The percentage of alumina indicates that it lies on the border line between the aluminous and the non-aluminous augites; chromium does not appear to have been specially sought for, but these bright green augites greatly resemble the chrome-diopsides of the lherzolites.

Silica	50·537
Alumina	3·348
Ferric oxide	1·338
Ferrous oxide	4·423
Manganous oxide	0·230
Lime	21·419
Magnesia	17·050
Potash	0·252
Soda	0·530
Water	0·706
	99·833

In the great majority of these rocks, however, the augite is of a black colour by reflected light, and when viewed in thin sections exhibits various tints from light to dark brown.

Although no analyses have been made of these black augites of the Scottish gabbros in their unaltered condition, yet the following analyses of the forms which have undergone the curious redistribution of their materials described in this paper will no doubt serve to show the general proportions of the several bases in different varieties.

* Trans. Roy. Soc. Edinb. vol. xxviii. (1879) p. 478.

	I.	II.	III.	IV.	V.	VI.
Silica	51·362	50·80	53·046	51·936	51·30	49·268
Alumina	1·662	3·00	4·816	1·322	0·76	0·222
Ferrous oxide......	8·968	9·61	11·389	13·900	13·92	14·080
Manganous oxide	0·332	1·08	0·078	0·250	0·25	0·381
Lime	20·837	19·35	19·808	19·363	20·15	20·256
Magnesia	16·471	15·06	11·576	13·850	14·85	14·812
Soda		0·66				
Titanic acid				0·380		
Water...............	0·540	0·60	0·626	0·200	0·21	0·719
	100·172	100·16	101·339	101·201	101·44	99·738

I. Analysis by Heddle of an altered diallagic augite of green colour, specific gravity 3·329, from Hart o' Corry, Cuchullin Hills, Skye (Trans. Roy. Soc. Edin. vol. xxviii. (1879) p. 479).

II. Analysis by Haughton of augite from Loch Scavaig, Skye (Dublin Quart. Journ. Geol. Soc. vol. v. (1865) p. 95).

III. Analysis by Heddle of greyish green altered diallagic augite from Corry na Creech, in the Cuchullin Hills, Skye, sp. gr. 3·329 (*loc. cit.*).

IV. Analysis by Heddle of brownish-green diallagic augite from Drum-na-Rabn, in the Cuchullin Hills, Skye, sp. gr. 3·335.

V. Analysis by Vom Rath of diallage from Skye: see Rammelsberg, Handbuch der Mineralchemie, 1st ed. (1860) p. 465.

VI. Analysis by Heddle of dark-green diallagic augite from Loch Scavaig, Skye, specific gravity 3·321 (*loc. cit.*). (Iron estimated as ferrous oxide.)

These analyses show that the black augite, which is the most common constituent of the gabbros of the Western Isles has a proportion of ferrous oxide, varying from 9 to 14 per cent., while that of the green variety is only about 5 per cent. The lime averages 20 per cent.; but the proportions of alumina and magnesia are somewhat variable. The black varieties occur usually in crystals, which are sometimes of large size; the green varieties also form similar crystals but sometimes occur in more or less rounded grains.

The rhombic pyroxenes are very frequently present in these rocks, but are in almost all cases subordinate to the monoclinic forms. Owing to the confusion which has arisen with respect to the former group of minerals, it will be necessary to discuss at some length the question of the varieties which they present in the Western Isles of Scotland. The minerals belonging to the group of the rhombic pyroxenes which were first made known by mineralogists, and were described under the names of hypersthene (paulite), bronzite, diaclasite, and bastite, are all, as we shall show hereafter, in a more or less altered condition—the rhombic pyroxenes being remarkably subject to changes of several different kinds. But in the year 1855 Kengott discovered an unaltered mineral of the group, to which he gave the name of enstatite *, and in 1862 Descloiseaux demonstrated that it crystallizes in the rhombic system †. Shortly after this period other forms of unaltered rhombic pyroxenes were discovered—protobastite by Streng ‡, meteoric enstatite by Rammelberg § and Story-

* Sitzungsb. Akad. Wien, vol. xvi. (1855) 162.

† Bull. Soc. Geol. Fr. ser. 3, vol. xxi. p. 135.

‡ Neues Jahrb. für Min. &c. 1862, p. 513.

§ Monatsber. d. Akad. Berl. 1861.

Maskelyne,* amblystegite by Vom Rath †, and a similar mineral from Mont Dore by Descloiseaux ‡.

The minerals found in an unaltered form at these different localities were at first regarded as being excessively rare. But in 1879 Prof. Fouqué showed that the lavas of Santorin contain in great abundance an unaltered rhombic pyroxene which he referred to hypersthene §. In 1883, Mr. Whitman Cross demonstrated the existence and wide distribution of a large and important class of lavas, distinguished by the presence in them of a rhombic pyroxene which he also referred to hypersthene ||. In the same year Mr. Teall and Dr. Petersen pointed out that certain British rocks from the Cheviot Hills contain the same rhombic pyroxene ¶, and these, as shown by the former author, are of especial interest as being of pre-Tertiary age. Subsequent observations have shown these rhombic pyroxenes to be among the most widely distributed of the rock-forming minerals. Much attention was directed to them as constituting an important constituent of the pumice thrown out by Krakatoa during its last great eruption; and they have been found in the lavas of South America, Java and Sumatra, Japan, the Philippine Islands, and many other volcanic districts.

Nor are the rhombic pyroxenes less common among the plutonic than among the volcanic rocks. In the Schemnitz district the Tertiary diorites and quartz-diorites ** frequently contain a considerable proportion of the rhombic pyroxene, which, as in the associated lavas, has been generally confounded with the hornblende. Teller and Von John have described an interesting series of rocks of the same class from the Tyrol ††, and the diorite of Penmaenmawr has been shown by Rosenbusch and others to be an enstatite-diabase ‡‡.

The rhombic pyroxenes are bisilicates of magnesia and iron $(MgO, FeO) SiO_2$, in which the relative proportions of magnesia and iron may vary to almost any extent. Lime is often almost wholly absent, but appears to be capable of replacing, perhaps to a limited extent, the other bases.

It is well known that the colour, the physical properties, and the optical constants of varieties of the augites, the micas, and other similar groups, are modified in the most remarkable manner by the quantity of ferrous oxide or other bases in their composition. But in the group of the rhombic pyroxenes the variations in character dependent on composition are of the most extreme kind.

At one end of the series we have enstatite proper, a colourless mineral without trace of dichroism; but as the magnesia is replaced

* Trans. Roy. Soc. vol. clx. p. 204. † Poggend. Ann. (1869), cxxxviii. 531.

‡ Manuel de Minéralogie, tome. ii. (1874) p. xviii.

§ Santorin et ses Eruptions (Paris: 1879).

|| Bull. U. S. Geol. Survey, no. i.

¶ Geol. Mag. Dec. ii. vol. x. (1883) p. 346. J. Petersen, Mikroskopische und chemische Untersuchungen am Enstatit-Porphyrit aus den Cheviot Hills. (Kiel, 1884).

** See Quart. Journ. Geol. Soc. vol. xxxii. (1876) pp. 292–325.

†† Jahrb. k-k. geol. Reichsanst. vol. xxxii. (1882) pp. 589–584.

‡‡ Die massigen Gesteine, p. 352.

to a greater extent by ferrous oxide, the mineral becomes of a more and more pronounced brown tint with marked pleochroism. With the highest percentage of iron the mineral assumes a very dark colour, and when examined in thin sections exhibits the most startling pleochroism (*a*, brilliant red; *b*, duller red; *c*, bright green).

There has arisen much confusion as to the names which should be given to the different varieties of the rhombic pyroxenes. Most authors call the non-ferriferous varieties "enstatite," the more ferriferous kinds "bronzite," and still more highly ferriferous forms "hypersthene." Tschermak has proposed that varieties with less than 5 per cent. of ferrous oxide should be called enstatite, those with between 5 and 15 per cent. bronzite, and those with more than 15 per cent. hypersthene *. The strict application of this rule would, however, necessitate a chemical analysis in each case before the species or variety could be determined.

As a matter of fact, no two petrographers are agreed as to the limits between enstatite and bronzite, and between the latter mineral and hypersthene. Thus the mineral of the andesite of the Cheviot Hills, regarded by Mr. Teall as hypersthene, is, by Dr. Petersen, who carried on his investigations in Prof. Rosenbusch's laboratory, classed as bronzite †. The similar mineral found in the pumice of Krakatoa is called hypersthene by many authors and bronzite by others. The minerals classed as enstatite, bronzite, and hypersthene respectively by Rammelsberg ‡ do not conform to the rule laid down by Tschermak as to the chemical composition of these varieties.

The gabbros and peridotites of the Western Isles of Scotland contain all the varieties of the enstatite group, in both their altered and their unaltered forms; and these permit a careful study of the whole series of minerals. Through the replacement, to a varying extent, of a part of the magnesia by ferrous oxide, very distinct varieties are produced; but, inasmuch as the crystalline form remains the same, it will be convenient to treat the rhombic pyroxenes like the monoclinic pyroxenes ("augites"), and give them a common name. I think there can be no doubt that the common name for these rhombic pyroxenes should be "enstatite," for this was the first *unaltered* rhombic pyroxene which was detected and described by mineralogists. I believe that this is also the view taken by Prof. Rosenbusch.

As, however, the variation in the relative proportions of magnesia and ferrous oxides in these minerals leads to such startling differences in their appearance and optical properties, it may be necessary to use a number of varietal names—like those employed in the case of the monoclinic pyroxenes—diopside, common augite, and hedenbergite.

As the enstatites were till quite recent years entirely unknown to mineralogists in their unaltered forms, a difficulty arises in selecting

* Tschermak, 'Lehrbuch der Mineralogie' (1884), p. 436.
† See Geol. Mag. Dec. iii. vol. i. (1884) p. 227.
‡ Handbuch der Mineralchemie, 2nd ed. 1875, pp. 382–385.

appropriate names by which to designate the several varieties. The modifications of the ferriferous enstatites known as bronzite and hypersthene (paulite) respectively, are, as I shall show hereafter, alteration-products, and the structures which characterize them are by no means rigidly confined to varieties of a particular chemical composition.

The unaltered crystals of the rhombic pyroxenes differ so strikingly in their appearance and optical properties from those of the same composition in an altered state, that it is misleading to designate them by the same varietal name. Possibly the difficulty may be got over by following the example set by Streng in the case of bastite, and calling the unaltered forms of the minerals bronzite and hypersthene respectively proto-bronzite and proto-hypersthene. Accepting also the ordinary convention, that the name bronzite belongs to the less ferriferous, and the name hypersthene to the most ferriferous varieties, we may then perhaps indicate the chief types of the *unaltered* rhombic pyroxenes as follows:—

(1) Non-ferriferous enstatite (enstatite proper) containing less than 5 per cent. of ferrous oxide. A colourless or nearly colourless mineral destitute of pleochroism. Hardness 5 to 5·5. Specific gravity 3·1 to 3·2.

(2) Ferriferous enstatite (proto-bronzite). With a percentage of ferrous oxide ranging from 5 to 15. Pale coloured, with feeble pleochroism. Hardness about 5·5. Specific gravity 3·2 to 3·3.

(3) Highly ferriferous enstatite (proto-hypersthene). With a percentage of ferrous oxide ranging from 15 to 25. Darker coloured, with strong pleochroism. Hardness about 6. Specific gravity 3·3 to 3·4.

(4) Excessively ferriferous enstatite (amblystegite). With a percentage of ferrous oxide ranging from 25 to 35. Dark coloured, with intense pleochroism (colours from deep red to vivid blue-green). Hardness 6 to 7. Specific gravity 3·4 to 3·5.

While the crystalline forms and the goniometric measurements show no differences in these several varieties, the positions of the optic axes and other characters undergo great modifications according to their chemical composition.

The last named of these varieties of the enstatite group has not received the attention which it deserves. I have recently found that it occurs by no means rarely as a rock-constituent. Not only is it found, both in its unaltered and in its altered state, in the gabbros of the Western Isles of Scotland, but it occurs in the Newer Palæozoic lavas of Forfarshire and in the diorites of western Sutherland *. It is a widely distributed mineral, for I have found it in rocks from Norway, Saxony, southern India, western Africa, and the Solomon Islands, forming an important constituent of gabbros, diorites, quartz-diorites, andesites, and certain interesting ultra-basic rocks, while it appears to be almost always present,

* [I am indebted to my friend Mr. Teall for calling my attention, since the reading of this paper, to the rocks of this and several other localities in which the mineral in question occurs.]

sometimes in considerable quantities, in the so-called trap-granulites, the diallage-granulites, and other similar rocks all over the globe.

The analyses which have been made of these excessively ferriferous enstatites are as follows:—

	I.	II.	III.
Silica	49·80	48·2	51·348
Alumina	5·05		
Ferrous oxide	25·60	28·4	33·924
Manganous oxide		5·2	
Magnesia	17·70	16·7	11·092
Lime	0·15	1·5	1·836
Water			0·500
	98·30	100·0	98·700

I. Is the analysis by Vom Rath of the original "amblystegite" of the Laacher See. (Pogg. Ann. cxxxviii. (1869), p. 531.)

II. Is an analysis by Laurent of the dark-coloured enstatite found in cavities of a rock enclosed in the trachyte of the Rocher du Capucin, Mont Dore, quoted by Descloiseaux (Manuel de Minéralogie, tome ii. p. xviii.).

III. Is the analysis of the altered form of the same mineral, which will be referred to hereafter as occurring at Loch Coruiskh, in Skye. The analysis was made by Muir and published by Thomson ('Outlines of Mineralogy,' 2nd ed. (1822), vol. i. p. 202.

Although Prof. Vom Rath withdrew his name of "amblystegite" when he found from Von Leng's researches that all the planes of its crystals were represented in the enstatite of the Breitenbach meteorite *, yet if it be necessary to have a varietal name for these excessively ferriferous and strongly pleochroic enstatites, it would seem desirable to revive this term rather than to invent a new one.

The amblystegites differ from the ordinary hypersthenes in their unaltered state (proto-hypersthenes) quite as strikingly as do the latter minerals from the unaltered bronzites (proto-bronzites), or as these last do from the enstatites proper. In microscopic sections of rocks the wonderfully vivid pleochroism, which gives rise to colours varying from a rich garnet red to a vivid blue-green, is its most striking characteristic, and serves to distinguish it from all other rock-forming minerals. The only other rhombic mineral with characters which at all approach it is andalusite; but in practice the distinction of these two minerals is perfectly easy.

Among the remarkably fresh minerals of the Tertiary gabbros and peridotites it is possible to recognize all the varieties of the enstatite group.

In the island of Rum, we find a perfectly colourless rhombic pyroxene, occurring in irregular grains with a colourless olivine and the brilliant green diopside already described. In its perfectly fresh condition this enstatite can only be discriminated from olivine, also a rhombic mineral, with the greatest difficulty. The fine striation relied upon for the distinction of the two species is a

* Neues Jahrb. für Min. &c. 1871, p. 642.

result of alteration, and is not found in perfectly fresh forms of the mineral. In some cases I have only been able to verify the presence of enstatite by a micro-chemical method. In thin slices and in the powder of the rock the olivine is attacked by long digestion in strong hydrochloric acid, while the enstatite remains unchanged.

In other districts of the Western Isles of Scotland we find more ferriferous varieties of enstatite which must be referred to proto-bronzite and proto-hypersthene. Usually, these are in a more or less altered condition. In very few cases, so far as I have seen, is the enstatite the principal pyroxenic constituent of the rock, but it is subordinate to the augite. In small patches of these rocks, however, the augite may become subordinate to the enstatite, while occasionally the former mineral may be altogether wanting, the rock thus passing into a norite or hypersthenite.

Occasionally the dark colour of the mineral, when seen in the thinnest sections by transmitted light, and its strikingly vivid pleochroism, indicate that we are dealing with the excessively pleochroic enstatite, amblystegite (see Pl. XI. fig. 7). That Macculloch was acquainted with the altered forms of the enstatite in these rocks, I have the clearest evidence. A specimen given by Macculloch to the late Mr. Majendie passed into the hands of Mr. Warington Smyth, and by him was placed in the collection of the Normal School of Science and Royal School of Mines. An examination of the optical properties of this specimen shows it to be a rhombic and not a monoclinic pyroxene.

Intergrowths of the monoclinic and rhombic pyroxenes occur not unfrequently in the gabbros and peridotites of the Western Isles of Scotland, and crystals of the one mineral are sometimes found enclosed in the other. I have not, however, detected examples of the twin-intergrowths of the two minerals described by Trippke *.

The *Olivines* of the gabbros and peridotites of the Western Isles of Scotland appear, like the associated augites and enstatites, to belong, in some cases, to the most highly ferriferous varieties. Seen in thin sections under the microscope, these olivines are often found to be by no means colourless, like most of the olivine of basalts, but exhibit a yellow tint similar to, but not so intense as, the tint of the fayalite in eulysite. Such deep-coloured olivines are abundant in the Shiant Isles.

Some of the olivines of these rocks are perfectly fresh and unweathered, but occasionally the mineral shows incipient traces of serpentinization along its cracks. Occasionally another kind of change has taken place resulting in the mineral acquiring a yellow tint along its fissures, which causes it to assume the colour and aspect of chondrodite. Similarly altered forms of olivine from the Kaiserstühl have received the names of "chusite" and "limbelite".

An analysis of this curiously altered olivine from the summit of Halival in the island of Rum, was made by Dr. Heddle and is as follows † (its specific gravity was found to be 3·327):—

* Neues Jahrb. für Min. &c. 1878, p. 673.

† Mineralogical Magazine, vol. v. (1884) p. 16.

Silica	38·006
Alumina	0·286
Ferric oxide	2·933
Ferrous oxide	18·703
Manganous oxide	0·100
Lime	0·336
Magnesia	38·000
Water	1·587
	99·945

This analysis indicates a very ferriferous olivine approaching in composition to the variety known as hyalosiderite.

The Spinellids.—Among the essential minerals of these rocks are the minerals which have been grouped by Fouqué and Lévy under the convenient name of the spinellids, namely magnetite, chromite, and picotite. These minerals, which are isomorphous, have now been shown to pass into one another, by insensible gradations as the proportion of chromic acid varies *. The first is opaque, the two others more or less translucent and of a brown colour. Magnetite is the mineral which is usually found in the gabbros; chromite and picotite in the peridotites.

It may be mentioned that, as has been proved by Dr. Hodgkinson, of the Normal School of Science, all these rocks contain copper. It is probable that nickel and cobalt are also present in varying quantities, as well as chromium, manganese and iron; but in ordinary analyses no attempt is made to isolate the oxides of these metals.

Biotite—represented usually by a highly ferriferous and very dichroic variety, is among the most common of the accessory minerals of these rocks; in some cases it becomes so abundant as to deserve to be regarded as an essential constituent of the rock.

Metallic Iron.—By the employment of Prof. Andrew's method, Mr. J. T. Buchanan has succeeded in proving that some of the iron in the gabbros of the Western Isles of Scotland is in a metallic condition.

§ 4. The Changes which the Minerals of these Rocks have undergone at Great Depths from the Surface.

The great intrusive masses of the West of Scotland are of especial interest to geologists, inasmuch as they afford us an opportunity of studying the conditions assumed by the same minerals under varying conditions of depth and pressure.

The intrusions of basic rocks in Mull, Ardnamurchan, Rum, and Skye were originally of very different dimensions, those of Skye and Ardnamurchan being the largest, that of Mull coming next in size,

* Renard, Rep. Voyage H.M.S. 'Challenger,' vol. ii., Narrative, "On the Petrology of the Rocks of St. Paul," p. 10; Wadsworth, Mem. Mus. Comp. Zool. Harvard, vol. xi. (1884) p. 176.

while that of Rum is the smallest among the principal volcanic centres. Of still smaller intrusive masses, however, we have many examples, among which may be specially mentioned those of Sarsta Beinn in Mull, and the Shiant Isles, north of Skye.

These intrusive masses are fully exposed to our study, even their central portions being laid bare by denudation; and the results obtained by a comparative study, by the aid of the microscope, of examples derived from corresponding portions of masses of different size and of different portions of same mass, are of very great interest.

If my interpretation of the geological structure of the district be correct, it is a necessary inference that while the rocks of the Cuchullin Hills of Skye about Loch Coruiskh, and those forming the western extremity of Ardnamurchan, once existed at a great depth from the surface of the volcanoes of which they formed a part, the similar rocks forming the mountain masses of Mull and Rum existed at a smaller depth and under less pressure. Now I shall show that the several minerals of these rocks, when they have formed parts of masses at great depths from the original surface, often exhibit very striking and suggestive differences in their characters from those which have existed at smaller depths.

It will further be demonstrated that a precisely similar series of differences can be traced when the several minerals are followed from the more superficial to the more profound portions of each intrusive mass.

We shall describe minutely these changes in the case of each of the minerals forming these rocks. In these Tertiary rocks the question is fortunately not complicated or obscured by alterations which have been set up by weathering action; for, as a rule, the minerals are strikingly fresh and unaltered.

The Felspars.—The felspars of the more superficial portions of the intrusive masses, and also those in the smaller intrusions and apophyses, are usually remarkable for their strikingly clear and fresh appearance. Under the highest powers of the microscope they are seen to be traversed by many fine cracks, while a few cavities, some of which contain liquids with moving bubbles, are scattered through them. In such cases it may perhaps be inferred that the cavities were formed during the original development of the crystal, and that the cracks are due to the contraction of the mass during its cooling from its original high temperature.

In the felspars of rock-masses which were originally more deeply seated, this perfect clearness seems to be quite lost. Cavities, some of which contain liquid with spontaneously moving bubbles, are present in enormous abundance. Prof. Zirkel has already remarked on the extraordinary abundance of such enclosures in the felspars of the gabbros of Mull *. What is of especial interest however, is the fact that these cavities in many cases are seen to lie in fissures, or in bands parallel to fissures, in the crystal, and to be connected by minute ramifying tubular processes. In many

* Zeitschr. d. deutsch. geol. Gesell. vol. xxiii. (1871) p. 59.

cases, where no fissures can be detected, we find the crowding of cavities along bands similar to those which accompany the actual cracks. The explanation which I would propose to account for these interesting appearances is as follows:—When any part of a crystal is subjected to abnormal strain (and that such strains, resulting eventually in the fracture of the crystals, must be constantly set up in rock-masses is evident), then, according to a well-known physical principle, solvent action will be promoted along such bands of strain, and cavities containing liquids will be formed. Subsequently, and perhaps partly in consequence of the formation of the numerous cavities, actual rupture may take place along this band, which was first a plane of strain, and which, by the solvent action, has been converted into a plane of weakness in the crystal. This explanation also accounts for the fact that the same band of cracks may be found traversing a number of adjacent crystals in a rock. Similar facts have been noticed by Vogelsang, Kalkowsky, Jullyan, Phillips, and other authors (see Pl. X. fig. 2). In some cases the liquid-enclosures are so numerous that the supersaturated solutions in them can be detected by chemical methods. If a crystal full of liquid-enclosures be carefully washed and, after being crushed, treated with distilled water, the liberated sulphates and chlorides will give distinct precipitates with chloride of barium and nitrate of silver. In many cases the enclosures are now seen to be filled up with solid substances, as was pointed out to be the case in the rocks of Brittany by Mr. C. Whitman Cross * (Pl. X. fig. 3).

At still greater depths, as in the rocks of the Cuchullin Hills and the western extremity of Ardnamurchan, a more or less complicated avanturine structure is exhibited by the felspar. Minute black rods and plates are seen to be developed along one, two, three, four, or even more planes within the crystal. The planes along which these enclosures are formed appear to be parallel to the macropinacoid, the brachypinacoid, the two prism-faces and the basal plane (see Pl. X. figs. 4, 5, 6); and the planes exhibiting these peculiarities appear to be affected in the order in which we have named them.

The dimensions of these brown rods and plates, enclosed in the felspar crystals, vary within very wide limits. Occasionally they are sufficiently large to be seen by the naked eye; usually they are of microscopic dimensions, while they sometimes require the use of the very highest powers to discriminate their forms and characters.

In Ardnamurchan and Skye we find examples of gabbros in which the felspars exhibit a brown tint, and in thin section the colour of the crystals is seen to be due to the existence of nebulous masses of foreign materials distributed irregularly through them. The highest microscopic objectives at my command only just serve to partially resolve these nebulous masses into series of rods and plates, arranged along certain planes within the crystal, and only distinguished from those already described by their smaller dimensions (see Pl. X. fig. 7).

* Min. und petr. Mitth. vol. iii. (1880) p. 374.

From these inclusions, which are of such minuteness as only to be imperfectly seen with the highest powers of the microscope, it is easy to make the transition to others which are absolutely ultra-microscopical, but which can be detected by the effect which they produce on the light-waves that traverse the crystal.

In this way we are led to the understanding and interpretation of another peculiarity possessed by the felspars in the most deeply seated masses, which is especially worthy of notice. Such felspars not unfrequently display the *chatoyant* effects so characteristic of some of the labradorite from Labrador, while the felspars formed at less depths never exhibit this peculiarity.

According to Breithaupt, the labradorite exhibiting a play of colours has a different density from the varieties without that peculiarity; and Von Bonsdorf has shown* that while the former has a percentage of silica of 57, the latter has one of only 52.

The researches of Reusch †, Schrauf ‡, and many other investigators have shown that this play of colours is due to a series of thin plates, developed along certain planes within the crystal. These plates appear to be of ultra-microscopical dimensions, but by producing interference give rise to the exquisite play of colour exhibited by brachydiagonal sections of the crystal when held in certain positions. Although it is impossible to trace the structure to which this peculiarity is due by means of the microscope, yet the circumstance of its being exhibited only in the felspar of deep-seated rocks is of great significance when considered in connexion with the other phenomena which we have just described.

By the study of a large number of examples, it is clearly seen that these changes are quite independent of the passage through the crystals of water from the surface, which produces kaolinization, and sometimes leads to the penetration of serpentinous and other decomposition-products, along lines of fissures into the interior of the felspar crystals. These and other important alterations which have been superinduced in the felspar-crystals of these deep-seated rocks, subsequently to their original formation, we hope to discuss in a future paper. The different changes we have been describing, like the analogous ones in the pyroxenes and olivines, are, however, clearly related to the *depth from the surface* at which the rocks were originally situated, the greatest change being in every case displayed by the most deeply seated rock-masses.

The Pyroxenes.—Both the monoclinic pyroxenes (augites) and the rhombic pyroxenes (enstatites) exhibit in a very striking manner the effects of alteration when they form parts of rock-masses originally situated at great depths from the surface.

By the old German miners the name of "Schiller-spar" was given to those mineral substances which exhibit a "Schiller" or sheen, *i.e.* a submetallic reflection when the crystal is held in certain positions. Freiesleben and the early German mineralogists

* Jahrb. für Min. &c. (1838) p. 681.

† Poggend. Ann. vol. cxvi. &c.

‡ Sitzungsb. der k. k. Akad. Wien, vol. lx. (1869).

adopted the term "Schiller-spar" as the name of a mineral species; but Breithaupt, Haidinger, and Haüy, by dividing the Schiller-spars into species like diallage, diaclase, bastite, and hypersthene, showed that they had recognized the fact that many different minerals may exhibit the peculiar reflection of Schiller-spar.

It is now recognized that many varieties, both of the monoclinic and of the rhombic pyroxenes, under certain circumstances, may exhibit this peculiar appearance. The different kinds of pyroxene, with the corresponding "Schiller" varieties, may be classed as follows:—

	Unaltered forms.	"Schiller" varieties.	More altered form.
ENSTATITES, Rhombic.	Enstatite proper.	Diaclasite ?	Talc (?)
	Proto-bronzite.	Bronzite.	Bastite.
	Proto-hypersthene.	Hypersthene.	
	Amblystegite.	Hypersthene.	
AUGITE, Monoclinic.	Diopside. Augite proper. Hedenbergite.	Diallage and Pseudo-hypersthene.	Green diallage. Smaragdite, &c.

The "Schiller"-varieties of pyroxenes, when examined in thin sections under the microscope, are seen to owe their peculiar appearance to the presence in them of a great number of enclosures, in the form of thin plates or delicate rods, arranged along one or more sets of parallel planes within the crystal. When the crystals are held in certain positions, the numerous enclosures, which exhibit various grey, yellow, and brown tints, and possess a submetallic lustre, reflect the light traversing the transparent portions of the crystal, and by this reflection give rise to the "Schiller" phenomenon.

The crystals of augite like those of felspar exhibit the first traces of alteration along the incipient cracks, whether due to cleavage or other causes, which traverse them. Along these incipient cracks and in bands parallel with them, cavities make their appearance, some of these cavities containing liquids with moving bubbles, while others enclose solid materials (see Pl. XI. fig. 1). While the augites of the superficial rocks contain but few of these enclosures, they become exceedingly numerous as we trace the augite crystals to greater distances from the original surface. It is therefore impossible to doubt that these cavities formed in networks along the incipient cracks of the crystal are, like the similar ones described in the felspars, of secondary origin. They have probably been formed by the solvent action of the fluids which now fill them, acting under the enormous pressures consequent on their original depth from the surface.

Both the green augites (diopside) and the black varieties (common augite) of the Western Isles of Scotland are found, when traced into the more deeply seated masses, to pass gradually into the "Schiller" varieties known as diallage and pseudo-hypersthene. That this is the result of a secondary modification is proved by the fact that the alteration of the crystals is seen in many cases to be confined to their outer portions, so that a nucleus of ordinary augite is sur-

rounded by a shell of diallage (see Pl. XI. fig. 3); in other cases the alteration of the augite into diallage is seen to take place along cracks, due to cleavage or other causes, which intersect the crystal (see Pl. XI. fig. 5); in other cases, again, the alteration into diallage is found to occur in irregular patches within the augite, though the cause of the distribution of these altered patches may not be manifest from a study of the thin section.

Although the alteration of the augite may be set up along the cleavage-cracks of the crystals, yet the position of the brown enclosures bears no relation to the principal (prismatic) planes of cleavage in the mineral. On the contrary, the enclosures appear to be developed in planes parallel to the orthopinacoid planes, in which only a very imperfect cleavage exists in augite *.

In the island of Rum, the augite, though exhibiting the first traces of the development of the structure which is characteristic of diallage, is seldom so far altered as to deserve being called by that name. In the larger igneous masses of Mull, the augite in all the central portions is in the condition of diallage, as was pointed out by Zirkel. Between rocks in which the augite is entirely unaltered, and those in which it is completely transformed into diallage, every possible transition may be found.

In the central portions of the largest intrusive masses, those of Skye and Ardnamurchan, the augite exhibits a still further modification. In addition to the enclosures along the planes parallel with the orthopinacoid, other enclosures make their appearance in planes cutting these at an angle of $87\frac{1}{2}°$, or parallel with the clinopinacoid. The ordinary sections in which these two sets of enclosures are seen intersecting one another at different angles, according to the direction in which the sections traverse the crystals, present a singular "cross-hatched" appearance; but it is easy to trace every gradation from the variety with enclosures developed along one set of planes, to that in which they appear along two sets of planes. Frequently another set of enclosures may be detected as making their appearance along a third set of planes, which appear to be parallel to the basal plane † (see Pl. XI. figs. 4 & 6).

It is especially noteworthy that the colour, lustre, and general

* The curious augite of the Whin Sill, described by Mr. Teall (Quart. Journ. Geol. Soc. vol. xl. (1884) pp. 647–650) as presenting a foliated structure parallel to the basal plane, not improbably owes its peculiarity, as suggested by Prof. Rosenbusch, to an intergrowth of different minerals, or possibly to lamellar twinning on those planes of ultra-microscopical dimensions. (See also Vom Rath, Zeitschr. für Krystall. &c., vol. v. (1881) p. 495.) Prof. Rosenbusch is inclined to regard the foliation of diallage as connected with the existence of lamellar twinning parallel to the orthopinacoid (Mikroskopische Physiographie, vol. i. p. 303), a view which does not appear to be shared by most other petrographers. The enclosures in planes parallel to the orthopinacoid in augite, though the first formed, usually exhibit a tendency to indefiniteness and irregularity not seen in those parallel to the clinopinacoid and the basal plane.

† Tschermak has pointed out that the foliation-planes in diallage sometimes deviate by as much as 15° from the true orthopinacoid, and suggests that this may be the result of pressure. A similar but smaller divergence from symmetrical development of the foliation planes is said to occur in hypersthene.

aspect of the augite-crystals is completely altered by the development within them of these enclosures. The green and black augite acquires a greyish or brownish grey tint and a submetallic lustre along the planes of foliation. In this condition diallage is exactly analogous to bronzite in the series of rhombic pyroxenes. These characters appear to be intensified by weathering action, which seems to act with great facility along the planes of foliation, giving rise to the formation of laminæ of calcite and other secondary minerals, as was pointed out both by Tschermak and Bořický. Under these circumstances the green variety of diallage has its origin in a partial conversion of the augite-substance into hornblende, with other accompanying changes.

The development of two or three sets of enclosures in mutually intersecting planes causes the crystals of augite to acquire the deep-brown tint and the bronzy lustre of common hypersthene (paulite). In this condition the mineral has received from Dana the name of "pseudo-hypersthene." In its microscopic characters, no less than in its colour and lustre, it exhibits such a striking resemblance to the altered forms of the rhombic ferriferous enstatites (the substance to which the name of hypersthene was originally applied) that we may cite it as a very remarkable example of *mimicry* in the mineral kingdom.

The enstatites, and especially their more ferriferous varieties, exhibit the same development of enclosures along certain planes which is found among the augites. Sometimes one such set of planes is developed, and the result is a mineral identical in character with the bronzites and bastites; at other times two or more sets of such enclosures are developed along mutually intersecting planes, resulting in an appearance like that of the typical Labrador hypersthene or paulite. As already pointed out, such a variety was certainly collected by Macculloch in the Cuchullin Hills of Skye, and the same mineral was probably analyzed by Muir.

In the rock of Coruiskh the very highly ferriferous enstatite (amblystegite) occasionally occurs in a perfectly unaltered state. It then appears as a mineral of a rich brown colour, which, in thin sections, shows the striking dichroism already referred to, the colours changing from a rich garnet-red to blue-green. In other crystals, however, the commencement of change is exhibited by the development of enclosures along planes parallel to the brachypinacoid (see Pl. XI. fig. 9). The ferriferous enstatites having one set of interpositions developed within them, exhibit the submetallic reflections and the striated appearance under the microscope so characteristic of diallage. It is not surprising therefore that the foliated enstatite (bronzite) and the foliated augite (diallage) have been so frequently mistaken for one another.

In many cases a second, third, and even a fourth set of enclosures are seen to be developed within the enstatite crystals, in planes parallel to the macropinacoid, and the prismatic faces (see Pl. XI. fig. 8). We thus get the structure produced which is so well known as being characteristic of the original hypersthene (paulite)

of Labrador. The development of the additional series of enclosures causes the mineral to assume a much darker brown tint, while the submetallic reflections become less pronounced.

It does not, however, appear that the presence of one series of enclosures is absolutely characteristic of the less ferriferous enstatites, and that the two or more sets of enclosures are confined to the more highly ferriferous varieties. On the contrary, the same crystal may be altogether free from enclosures in one part, may exhibit one set of enclosures in another part, and thus assume the appearance of bronzite, while at certain points within the crystal a second and a third set of enclosures may appear, and the hypersthene structure be produced (see Pl. XI. fig. 5). Other things being equal, however, the bronzite-structure is perhaps more likely to be produced in less ferriferous varieties, and the hypersthene structure in the more ferriferous. It is probably too late now to prevent the use of the terms bronzite and hypersthene for varieties differing in *composition,* otherwise it would be well if the names could be applied to distinguish these differences of *structure.* The parallelism between the varieties of the monoclinic and rhombic series of pyroxenes is complete. In the one series we have a perfect "mimicry" of the members of the other series:—

Common Augite corresponds to Ferriferous Enstatite.
Diallage corresponds to Bronzite.
Pseudo-hypersthene corresponds to Hypersthene.

The slight differences of colour between diallage and bronzite, and between pseudo-hypersthene and hypersthene, are not sufficiently constant to be relied upon for the discrimination of these minerals; the only certain means of distinguishing between them being the measure of the cleavage-angle, or the determination of the extinction-angle in the sections for indicating their system of crystallization.

We have seen that diallage is prone to a further change by the conversion of the augite-substance into green hornblende, and even the separation of calcite along its foliation-planes. By the commencement of this change we get the beautiful green diallage; while its completion results in the formation of smaragdite, actinolite, or similar amphiboles.

The enstatites are still more susceptible to changes of the same kind, but the resulting product is altogether different. By taking up water the enstatite substance of the crystal becomes more or less converted into green serpentinous or steatitic substances.

The greater ease with which the enstatites undergo alterations of this kind than do the augites, is shown by the fact that while the diallage of the Hebridean gabbros and peridotites is almost always unaltered, the enstatites associated with them nearly always exhibit the first symptons of decomposition, and are not unfrequently entirely converted into the *bastite*-modification.

The Olivines.—A change analogous to that taking place in the felspars and pyroxenes, is found affecting the olivines when they are traced to great depths from the surface. This change consists in the

separation of a black or dark brown, usually opaque, substance, probably magnetite and other iron-oxides, along certain planes within the crystals. But in the olivines the separated material assumes very peculiar and highly characteristic forms. In 1871 Prof. Zirkel, in describing the olivines of the gabbros of Mull, pointed out that they contained great numbers of blackish or brownish needles arranged in curious combinations, of which he gave a drawing*. Prof. Zirkel insisted on the fact that similar appearances are never found in the olivines of basalt, but that they occur in the olivines of many gabbros like those of Volpersdorf, the Valteline, and other localities. He also pointed out the fact that these dark inclusions sometimes become so numerous in the olivine as to render the mineral black and opaque, so that it may be easily mistaken for magnetite, except in very thin sections which have been carefully prepared to illustrate the structure of the mineral. Dana has also pointed out this change of olivine into a black opaque substance resembling magnetite, often exhibiting a fissile structure similar to that of mica†, and Wadsworth has described the same phenomenon.

The study of a series of specimens which have originally existed at different depths from the surface, in the Western Isles of Scotland, enables us to fully understand and explain this interesting change. This is rendered more easy by the fact that the results are, in this case, not complicated by serpentinization, a totally different kind of change due to quite other causes.

The first appearance of the change in question takes place along those irregular fissures that so frequently traverse olivine-crystals. Along these incipient or completed fissures, when they are examined by the aid of high powers, small stellar-groups of black or deep-brown filaments are seen making their appearance mingled with reticulations of cavities containing liquid or solid substances, like those formed in the felspars and pyroxenes. The stellar groups have much the appearance of dendritic markings (see Pl. XII. figs. 1, 2), and when seen foreshortened, or partially within the range of view of the higher powers of the microscope, present the characters represented by Zirkel‡. Sometimes these star-like bodies become crowded together so as to make the surfaces of the cracks and sometimes also the outer portions of the crystal black and opaque (see Pl. XII. figs. 3, 4).

Precisely similar appearances then make themselves visible along certain planes within the crystal, which are certainly parallel to the optic axis, but the more exact crystallographic relations of which I have as yet been unable to determine. With these stellate groups of fibres flat brown plates, like those appearing in the pyroxenes, sometimes appear in considerable numbers. Examples may be found of the gradual conversion of the stellate enclosures into tabular ones, by the filling-in of the intervals between the rays

* Zeitschr. d. d. geol. Gesell. Bd. xxiii. (1871) pp. 59, 60.
† System of Mineralogy, 5th ed. (1875) p. 258.
‡ Zeitschr, d. deutsch. geol. Gesell. vol. xxiii. (1871) p. 59, Taf. iv. fig. 11.

of the star (see Pl. XII. figs. *5a*, *5b*, *5c*). As these inclusions multiply, the crystal loses its translucency and finally becomes opaque, and exhibits by reflected light the colour and lustre of magnetite. As the tachylytes of the Western Isles of Scotland are rendered perfectly black and opaque by the quantity of magnetite-dust which they contain, so the olivines are completely obscured in their characters by the development in their midst of these magnetite-enclosures. What is taken for magnetite in many gabbros is nothing but this greatly altered olivine. That these stellate bodies in the substance of the olivine crystals are really inclusions formed within cavities having a rectilinear outline, is demonstrated when they are examined with high powers of the microscope. Each ray of the star is then seen to end abruptly along a right line, and the limits of the cavities within which they are formed are thus clearly indicated (see Pl. XII. fig. *5c*). The curiously varied forms represented by Zirkel are due to portions only of these stellate bodies being within the field of view of the microscope at the time and often being viewed obliquely; but by carefully focussing up and down, their true nature can be readily made out*. In their absolute dimensions these enclosures of the olivine crystals vary between very wide limits, as is the case with the similar bodies in the felspars and pyroxenes; while some of the enclosures can be seen and studied with quite low microscopic powers, others are crowded into a nebulous haze which can only be resolved by the very highest powers.

The Biotites, which are among the most frequent of the accessory minerals in the gabbros and peridotites, exhibit a similar secondary structure to that described in the felspars, the pyroxenes, and the olivines. Tabular enclosures of a deep brown or black colour are developed along the planes of easy cleavage of the mineral, and are sometimes so abundant as to render the mineral almost opaque (see Pl. XII. figs. 8, 9).

§ 5. Nature and Origin of the Changes which have taken place in the Minerals of deep-seated Plutonic Rocks ("Schillerization").

We have seen that alike in the felspars, the pyroxenes, the olivines, and the biotites of plutonic rocks, there is evidence of progressive change taking place at gradually increasing depths. This change consists in the development along certain planes within the crystals of tabular, bacillar, or stellar enclosures, which, reflecting the light falling upon them at certain angles, give rise to the peculiar phenomenon expressed by the term "Schiller." It will be convenient to have a general name for this kind of change, and I propose to employ the term "Schillerization" to express it. Thus I shall call diallage and pseudo-hypersthene "Schillerized augites,"

* Zeitschr. d. deutsch. geolog. Ges. vol. xxiii. (1871) pl. iv. fig. 11. Zirkel, Mikroskop. Beschaff. der Min. und Gest. (1873) p. 214.

bronzite and the typical hypersthene of Labrador "Schillerized ferriferous enstatites."

The nature of the enclosures which give rise to the "Schiller" phenomenon of minerals has been investigated by many mineralogists; but, as might have been anticipated when their minute size is taken into account, the results arrived at are very discordant*.

The enclosures vary in colour from grey to yellow, and through various shades of brown to purplish red; while they are sometimes so dark as to be almost black and opaque. In all cases, so far as it is possible to examine such minute objects, they prove to be isotropic. As a general rule, they are found to be infusible, and to resist the action of the strongest hydrochloric and other acids.

In form, these enclosures greatly vary. Sometimes they appear to have very definite outlines, which has led them to be regarded as microscopic crystals of hæmatite, magnetite, brookite, augite, or other minerals; but these identifications have not only not been supported, but in many cases have been actually disproved by chemical analysis. Nevertheless the regularity of their forms in the same crystal, and sometimes a wonderful agreement in the angular measures which they give, are very striking facts. In other cases, as for example in the Labrador hypersthene, the tabular enclosures, while presenting perfectly flat and parallel sides, exhibit the most irregular contours along some of their edges, and their forms appear to be quite irreconcilable with the hypothesis that they are microscopic crystals.

From a consideration of all that has been adduced by other investigators, taken in connexion with my own observations, I am led to the conclusions that the substances forming these various enclosures do not consist of any definite chemical compounds assuming the regular crystalline forms belonging to mineral species, but that they are mixtures of various oxides in a more or less hydrated condition, such as hyalite, opal, göthite, and limonite; hence their isotropism, their variation in colour, and their resistance to the action of acids.

All Schillerized minerals on analysis yield a small but notable proportion of water, which is probably contained in these enclosures.

The suggestion which seems to me to be most in accord with all the facts of the case, is that these enclosures are of the nature of *negative crystals* which are more or less completely filled with products of decomposition of the mineral. When these negative crystals are completely filled with foreign substances, the enclosures assume the outlines of true crystals, though they do not, of course, exhibit their optical properties; it is noteworthy that in some cases a correspondence between the angles of the enclosing mineral and the inclusions seems to have been clearly made out. But in other cases the secondary products are insufficient to fill the whole cavity

* This subject has been especially treated of by Scheerer (Pogg. Annal. lxiv. 1845); Vogelsang (Archiv Neerland. iii. 29, 1868); Kosmann (Neues Jahrb. f. Min. &c. 1869, p. 532); Hagge (Mikroskop. Untersuch. über Gabbro, &c. 1871); Trippke (Neues Jahrb. f. Min. 1878, p. 676).

of the negative crystals, and occupy irregular spaces within them. In some cases, like that of the olivines, the distribution of these products of decomposition within the negative crystals is partially determined by crystalline forces, and curious dendritic forms, of microscopic dimensions, are the result. That this is really the explanation of the dendritic forms seen in olivine, is shown by the fact that the ends of the star-like masses are bounded by straight lines, the sides of the negative crystals (see Pl. XII. figs. *5a*, *5b*, *5c*).

It is a very noteworthy circumstance that these negative crystals are formed along certain definite planes within the original crystal. The studies of the so-called "Aetzfiguren" by Exner, Baumhauer, and others have shown that the surfaces of crystals, and of sections of crystals, are very unequally affected when submitted to the action of appropriate solvents. The peculiar disposition of molecules in a crystal which causes it to yield most readily along certain planes to the mechanical forces applied in scratching and fracture, and which permits the waves of light and heat to traverse it at different rates in different directions, is equally manifested when the crystal is operated upon by solvent agents. We can understand how, under these circumstances, solution is set up along certain planes within the crystal, innumerable negative crystals being formed, while the products of decomposition are deposited within them. The action may be compared to what takes place when a beam from the sun or an electric lamp is passed through a block of ice. The beautiful ice-stars partially filled with water appear to be exactly analogous to the negative crystals formed by solvent action in augite, for example, and occupied by the hydrated oxides which result from its decomposition. Tschermak and others have pointed out that the lines along which solution takes place most easily are not necessarily the edges of cleavage-planes; and it has also been shown that the twinning of crystals modifies the "Aetzfiguren," as it certainly does the position of the plane of most easy chemical action, as revealed by the phenomena of Schillerization (see *Ante*, p. 379).

There is one point in connexion with this subject which appears to me to be specially worthy of attention, though, as far as I am aware, its importance has hitherto been very generally overlooked. The "Schillerization" of dark-coloured ferriferous minerals, like proto-hypersthene and augite, results in the discharge of colour from the substance of the crystal; and instead of a dark green or brown substance, we get a nearly colourless one, within which the innumerable deeply coloured enclosures are distributed. Now, inasmuch as the chemical composition of the whole crystal is scarcely, if at all, altered by this molecular change, it is fair to conclude that the iron and other oxides which gave the colour to the crystal have been dissolved out and deposited in the substance of the enclosures.

That this is really the case, we have, I think, a singularly beautiful proof. The researches of many mineralogists have demonstrated that in the pyroxenes, the micas, and many other groups of minerals, a remarkable relation can be discovered between the proportions of certain ingredients, notably the iron, in different varieties, and

certain optical constants, such as the position of the plane in which the optic axis lies and the angle between the optic axes *.

The researches by which the optical constants of minerals have been determined have proved that not only do the colour and characteristic pleochroism disappear in the substance of crystals † which have undergone Schillerization, but that the position of the optic axes and the angle which they make with one another are also affected. This remarkable effect of the Schillerizing process is shown if we compare unaltered and altered examples of minerals of the same chemical composition with one another, augites with diallages and pseudo-hypersthenes, ferriferous enstatites with bronzites and hypersthenes. Tschermak even points out that the optical constants of diallage are practically the same as those of diopside ‡. In the latter mineral ferrous oxide was almost absent from the first; in the former it has been to a great extent removed from the substance of the crystal and collected into the enclosures during the process of Schillerization.

§ 6. The Agency by which the Schillerization of Minerals has been effected.

In seeking for the causes which have produced in minerals the very remarkable changes which we have grouped together under the name of Schillerization, there are two very important facts which must be borne in mind. In the first place such changes are quite distinct from those which result from weathering action, or the penetration of water from the surface. Under the influence of this kind of action, felspars are more or less completely kaolinized, and their elements may subsequently recrystallize as zoisite and other minerals; augites are converted into uralite or directly into hornblende, and olivines and enstatites into serpentine, steatite, and talc. But in the minerals of the rocks we are describing, it is manifest that crystals which do not exhibit the smallest trace of Schillerization may be completely altered by weathering action; and, conversely, crystals which are perfectly fresh and undecomposed may have undergone the most striking effects of Schillerization. In cases where the results of weathering action have been superinduced upon those following from Schillerization, very complicated phenomena may be presented, which it may require much care to unravel. Cases of this kind we shall proceed to consider in the second part of this paper. But the examples of the Western Isles of Scotland are

* See for the pyroxenes, Tschermak, Mineral. Mitth. vol. i. (1870); Wilk. Zeitschr. f. Kryst. vol. viii. p. 208 (1884); Dölter, Neues Jahrb. f. Min. &c. 1885, vol. i. p. 43.

† It is true that slices of hypersthene viewed with a dichroiscope appear strongly pleochroic. But when examined with a high power, the substance between the enclosures is seen to be nearly colourless, and to exhibit only faint traces of pleochroism. In examining the whole slice of the mineral the light transmitted by the brown enclosures is affected by the intermediate substance, and a general effect of pleochroism is produced, which is not seen in either crystals or enclosures separately.

‡ Lehrbuch für Mineralogie (1883), p. 440.

particularly valuable for the purposes of study; for there the felspars often show no trace of kaolinization, the augites no trace of uralitization or of amphibolization, and the olivines no trace of serpentinization; and yet these several minerals, as we have pointed out, exhibit in the most striking manner the effects of Schillerization.

The study of these rocks in the field has clearly demonstrated that the degree of Schillerization of the several minerals can be correlated with the depth from the surface at which the rocks have formerly existed. In the more deeply seated rocks the most perfect Schillerization has taken place, and in those at less depth fewer planes within the crystal have been attacked, all traces of the action disappearing when the rocks have existed near the surface.

That the action producing Schillerization is a *secondary* one is proved in several ways. It is perfectly true that enclosures are often formed in crystals during their growth, and that, at high temperatures and under great pressures, abnormal crystal-growths frequently arise. In this way it may be suggested that augite might always crystallize with the diallage- and pseudo-hypersthene-modifications, ferriferous enstatite with the bronzite- or hypersthene-modification, and so on. But against the acceptance of this suggestion several very important considerations may be urged. The contents of the negative crystals are evidently products of decomposition, hydrated oxides like chalcedony, opal, göthite, and limonite. Further, as I have already shown, the action of Schillerization can in many cases be seen to be set up from the surface of the crystals and along the cracks which traverse it. And, lastly, the enclosures are altogether absent from some crystals in deep-seated rocks, which appear to have escaped altogether from the action which has produced this phenomenon. Schillerization is thus proved to be due to local and not to general causes.

On these grounds, then, I think it is impossible to doubt that what are now crystals of diallage were once common augite, that the bronzite and hypersthene are altered ferriferous enstatites, and that the peculiarities of the deep-seated crystals of labradorite and olivine have been acquired since their original formation.

Bearing all these facts in mind, it appears impossible to resist the conclusion that the solvent agents which have produced Schillerization are the water and other fluids which have permeated the rock-masses, and that their solvent action has increased with the pressure, that is to say with the depth from the surface. I need only refer to the classical researches of Daubrée, Sorby, Guthrie, and others, as placing beyond all doubt the fact of the increase of the action of solvents by pressure.

When we remember the enormous volumes of steam and other gases given off by great volcanoes during their eruption, and further that these eruptions are continued through geological periods of vast duration, bearing in mind too that the evolution of these gases does not terminate with the violent activity of the volcanic vent, but is equally manifested during the "Solfatara stage," and that enormous tracts of volcanic rocks are found altered by surface-emanation of steam, we can well understand how potent must be the influences

which are operating simultaneously upon the deep-seated rock-masses below.

The circumstance of the crystals of such rocks being full of numerous cavities, many of which contain saturated solutions of the alkaline chlorides and sulphates, or are filled with solid substances like wollastonite and other silica-compounds, and of such cavities also enclosing carbonic acid in a liquid condition, all bear witness to the presence of these solvents and to the potency of their action under pressure.

The study of these deep-seated rocks at different depths shows that the water and other solvents which permeate the whole of the crystals under the enormous pressure attacks certain silica-compounds more readily than others; probably the compounds of silica with iron and the alkalies are among the first to pass into solution. Eventually the whole of the compound silicates yield to the solvent and are broken up; but this does not take place uniformly through the crystals. In the direction of certain planes within crystals the molecules are in a state of less perfect stability with respect to chemical agencies than others, and along these planes the solvents eat out for themselves hollows (negative crystals) which become filled with the hydrated silica, the hydrated ferric oxides, and other products of decomposition. At increasing depths new planes within the crystal become susceptible to the action of solvents, and fresh enclosures are formed along them. Thus, at moderate depths, the only planes along which augite-crystals are attacked by the solvents, and along which they have enclosures (infilled negative crystals) formed, are the planes parallel to the orthopinacoid; but at greater depths planes parallel to the clinopinacoid and the basal plane are similarly attacked. The planes of chemical instability are not necessarily identical in position with those of imperfect cohesion (cleavage-planes); indeed in many cases, as we have seen, they are wholly different. But in many cases the position of these planes of easy solubility in a crystal are clearly modified by the twinned condition of the crystal.

In some cases Schillerization consists only in a redistribution of the matter within the crystals. Thus diallage, as a general rule, differs in composition from augite only by the presence of a percentage of water which, as we have already seen, is probably combined with the materials which fill the negative crystals. But in many cases the dissolved material may be carried away from the crystal and deposited within the cavities of neighbouring crystals of different species. In this way ferric oxide, probably derived from the pyroxenes, olivines, and magnetite, comes to be deposited within the negative crystals of labradorite. In the end this process of Schillerization must result in the blending together in the most inextricable manner of materials derived from different crystallized minerals, and the whole characters of the rock may be completely altered.

It has long been known that the faces and cleavage-planes of crystals are attacked by appropriate solvents in an unequal manner, so as to give rise to the characteristic forms of two dimensions known as

Aetzfiguren. But the Schillerization of minerals consists in the production by natural causes of *Aetzfiguren* in *three* dimensions. It bears witness to the existence of certain planes within crystals along which a greater susceptibility to chemical action exists than in others. It proves that, while often independent of the directions along which mechanical force and the different kinds of radiant energy most easily act, the planes along which the chemical forces operate are modified and controlled by structures like twinning. All these conclusions are in complete harmony with the results which have been obtained by the study of the *Aetzfiguren*. The results attained by the observations and reasonings which we have been describing bear the same relations to those obtained by the study of the *Aetzfiguren*, as the phenomena of cleavage in a crystal do to the observations made on crystal faces by means of the sclerometer.

All the changes of which we have hitherto spoken are such as may be traced in their effects by the aid of the microscope; but the same forces probably lead to other modifications of the internal structure of crystals, which are altogether ultra-microscopical and quite incapable of being detected by direct vision. But as it is well known that light-waves are capable of being interfered with by structures too minute to be discerned by the human eye, so we can readily understand how solution along certain parallel planes within the felspar crystal may lead to the formation of thin plates or layers, probably composed of chalcedonic material, which give rise to the beautiful *chatoyant* effects exhibited by these minerals when they have been submitted to deep-seated action. We have already pointed out that the alteration in the density and chemical composition of these *chatoyant* varieties of felspar support the view that they have undergone the kind of change which we have been describing, and that, in the Western Isles of Scotland, this phenomenon is exhibited only by the felspars of what have been the most deeply-seated rock-masses.

§ 7. Varieties of the Tertiary Ultra-basic Rocks.

The Tertiary peridotites and other ultra-basic rocks differ from one another both in their mineralogical constitution and in their structure. Varieties corresponding to each of the rock-species which have been established for the different types of peridotite are easily recognizable in the Western Isles of Scotland. Thus in the Shiant Isles and in the central parts of Rum we find a rock almost wholly made up of grains of olivine enclosing rounded particles of chromite and picotite—a rock which must be classed with the "dunites." In various localities in the island of Rum, and also in the Shiant Isles, we find rocks consisting essentially of olivine and augite, and these must be classed as "picrites." Occasionally we find a considerable amount of a more or less ferriferous enstatite, with some picotite or chromite superadded to the ingredients of the last-mentioned rock, and we have then an analogue of "lherzolite." Some of the veins which intersect the gabbros and peridotites of Rum are wholly made up of a felspar (which, by its extinction-angles, its specific gravity,

and its flame-reaction, is proved to be anorthite) and olivine. I was at a loss to find any exact analogue of these felspar-olivine rocks; but Professor Bonney has pointed out to me that in some varieties of the forellenstein (troctolite) of Volpersdorf, in Silesia, the augite becomes inconspicuous and almost disappears, and we have a rock similar to the Scotch variety which I have indicated. Professor Bonney has found the same rock in an altered state at Coverack Cove in Cornwall*. Other veins and enclosures in these rocks consist of anorthite and augite, and may be classed with the eucrites (see Pl. XIII. figs. 1, 2, 3, 4, 5, & 6).

As all of these varieties of the Tertiary ultra-basic rocks are found passing into one another, and into the gabbros and dolerites, by an increase in the quantity of one mineral or by the diminution and disappearance of others, it will, I think, be more instructive to consider the varieties exhibited by the rocks of different localities when their microscopic structures are considered than to dwell upon the merely accidental varieties of mineralogical constitution.

It may be mentioned at the outset that, as a general rule, the peridotites vary in structure with the gabbros and dolerites with which they are associated. We thus find peridotites of granitic structure, others of granulitic structure, and others, again, of ophitic structure (see Pl. XIII.).

The most perfectly crystalline type of these peridotites is found in the valleys in the central part of the island of Rum. A typical example of these rocks collected near the road between Kinloch and Harris is highly crystalline, of a black colour with a few scattered felspar-crystals, and has a specific gravity of 3·18. The olivine of this rock is of a nearly black colour, owing to the abundance of magnetite enclosures it contains; it can, however, be distinguished from the augite by its lustre and its fracture. It is not surprising to find that Macculloch, misled by the unusual colour of the olivine, failed to distinguish that mineral; and, regarding the rock as being wholly composed of augite, he gave to it the name of "augite-rock."

Thin slices under the microscope show the rock to be essentially made up of large crystals of augite and olivine.

The augite is of pale greenish or brownish tint by transmitted light, and exhibits very faint dichroism; but its cleavage-cracks, which are well marked, are characteristic of the mineral. Both the cleavage- and irregular cracks of the mineral are marked by bands of enclosures, consisting of cavities, sometimes empty, sometimes containing a liquid with a bubble, but most commonly filled with a solid substance of a reddish brown, sometimes almost black colour. This augite only occasionally exhibits the first traces of a passage into diallage by the development of enclosures in planes parallel to the orthopinacoid.

The olivine of this rock is in the most beautifully fresh condition, and seldom shows any trace of serpentinization. It polarizes with

* Quart. Journ. Geol. Soc. vol. xxxiii. (1877) p. 909.

the usual brilliant colours, but presents a somewhat curious appearance from the abundant enclosures which it contains, causing it to appear of a dusty grey tint. The numerous fissures which traverse the olivine grains are often stained of a bright yellow colour; along them are developed numerous cavities which are seen in some cases to be united by a ramifying system of canals, and not unfrequently contain liquids with a moving bubble. In most cases, however, they appear to be filled with brown or black decomposition-products like those in the augite-crystals. Along the same fissures are seen to be developed the curious dendritic stars or networks of a black or brown colour, and these are sometimes present in such numbers as to render the planes of the fissures black and opaque. In addition to these enclosures along the planes of the fissures, other stellar ones make their appearance in prodigious numbers within the substance of the crystal, communicating to it the dusty appearance already described. These are seen to be arranged in a series of planes parallel to the optic axis of the crystal, and the star-like inclusions are often mingled with and pass into others in the form of thin brown or black plates.

Among the commonest of the accessory minerals of this rock are felspar, biotite, a ferriferous enstatite (hypersthene), magnetite, and chromite or picotite.

The felspar is a plagioclase, which in its altered condition offers a striking contrast to the fresh augite and olivine of the rock. It is full of cavities, and its substance is often seen to have undergone more or less complete conversion into various secondary products.

The biotite, when unaltered, is of a deep brown tint, but is often Schillerized by the development of dark-coloured enclosures in planes parallel to the basal plane. Under these circumstances the substance of the crystals becomes much paler in tint.

The ferriferous enstatite (hypersthene) exhibits the usual marked pleochroism of that mineral when undecomposed, but it usually shows a great tendency to serpentinous alteration.

The magnetite and chromite or picotite form only a very subordinate part of the rock. The latter mineral by its decomposition appears to communicate a very striking chrome-green tint to portions of the rock.

Some of the peridotites of the higher mountains in central Rum exhibit a far less perfectly granitic structure, small crystals and granules of olivine being mingled with finely granular augite, as in the porphyro-granulitic dolerites. They resemble such dolerites without their felspar. These rocks have a specific gravity of 3·09. The olivine of these rocks is often more or less darkened by the multitude of black stellar inclusions which it contains.

These granular peridotites of central Rum are intersected by veins of many interesting rock-varieties. Among these occur porphyritic peridotites consisting of large individuals of olivine scattered through a granular base of olivine and augite and gabbros,

with the several minerals sometimes disposed in bands parallel to the sides of the vein. (See p. 359.)

One of the varieties of peridotite in the island of Rum is a rock of such beauty as to have attracted the attention and excited the admiration of all visitors to the island *. It is found constituting considerable portions of the mountains of Halival, Haiskeval, and Tralival, and is seen passing everywhere into an augite-gabbro. Different portions of these great mountain-masses appear to vary chiefly in the quantity of felspar which they contain.

The felspathic varieties are true augite-gabbros, consisting of a very fresh felspar, often perfectly clear and glassy in appearance, a bright green augite, and an olivine which has undergone the peculiar alteration which makes it resemble in aspect chondrodite. The rock is sometimes fine-grained and at others very coarse-grained, and the mixture of colourless, bright-green, and yellow crystals is very striking.

The non-felspathic varieties are picrites and lherzolites, rocks having a specific gravity of about 3·20, the admixture of bright-green augite, and the yellow olivine with more or less enstatite, giving them a very beautiful appearance (see Pl. XIII. fig. 3).

The augite of these rocks is usually of a bright emerald-green tint by reflected light, and pale green passing into pale brown by transmitted light. It usually exhibits a very feeble pleochroism. The augite sometimes forms well-developed crystals, but more usually it exists as rounded grains, like those of coccolite. The composition of this diopside, or slightly ferriferous augite, is illustrated by the analysis quoted on p. 367. This green augite, as well as the pale brownish varieties which accompany it, is traversed in all directions by cracks which are marked by numerous enclosures, which are sometimes liquid- or gas-cavities, but are not unfrequently filled with dark-brown or black solid materials. These augites exhibit admirable illustration of the initial stage of Schillerization. A few scattered tabular enclosures make their appearance along planes parallel with the orthopinacoid, and these in other examples are seen multiplied until the augite becomes a typical diallage.

The olivines of these rocks form more or less rounded or oval grains, often enclosing globular particles of chromite or picotite, which are generally black or opaque at their centres, but slightly translucent, and dark-brown in colour at their edges. A very marked feature of these olivines is their yellowish or brownish-yellow tint, so different from that of the mineral in its normal condition. Under the microscope this peculiar colour is seen to be confined to the cracks which traverse the crystals in all directions. The yellow tint is present in cases where not the smallest trace of serpentinization can be detected in the crystal. Along these cracks we find the curious stellate enclosures being developed, and these

* See Jameson, 'Mineralogy of the Scottish Isles,' vol. ii. p. 51; Macculloch, 'The Western Isles of Scotland,' vol. i. p. 485; Heddle, Trans. Roy. Soc. Edin. vol. xxviii. (1879) p. 478.

may multiply till they form black bands, traversing the crystal in all directions; lastly similar inclusions, sometimes mingled with brown plates, make their appearance along a series of parallel planes traversing the crystal in the direction of the optic axis, and these increase in number till they communicate a dusty appearance to the crystal.

The accessory minerals of these peridotites of Halival and the adjoining mountains of Rum are as follows:—felspar, a clear variety, crystallizing in forms intermediate between the lath-shaped crystals of basalt and the broad forms common in the massive gabbros, is nearly always present in small quantities, and may increase in abundance till the rock passes into a gabbro; ferriferous enstatite (hypersthene), which, when it occurs with the granular variety of augite, also assumes similar granular forms, but is at once distinguished by its colour, its remarkable pleochroism, and its extinction in positions parallel to the vibration-planes of the crossed nicols; biotite occurs but rarely, while magnetite and chromite (or picotite) are universally present. It appears as though the opaque magnetite passes by insensible gradations into the translucent and deep-brown chromite or picotite.

The last, but by no means the least interesting, of these Tertiary peridotites of Scotland which I shall notice, is that which occurs in the Shiant Isles to the North of Skye; it exhibits the most beautiful example of the ophitic structure in these rocks.

The igneous rocks of these islands, as pointed out in my previous paper *, form a great intrusive sheet 500 feet in thickness forced between strata of Inferior-Oolite age. The vertical columns of this intrusive mass constitute, as Macculloch has pointed out, one of the most imposing spectacles in the British Islands. The columns, 500 feet long and from 4 to 6 feet in diameter, form a range of inaccessible precipices rising directly from the sea.

Owing to the rising of a storm, I was compelled to render my visit to these little-known islands shorter than I could have wished, and consequently I had an opportunity only of tracing the relations of the igneous to the sedimentary rock-masses, and of collecting the fossils from the latter. I was not able to devote any time to determining the relations of the different varieties of igneous rocks to one another. As many varieties of the rocks as possible were, however, collected from different parts of the island by myself and a friend, Dr. Taylor Smith †, who accompanied me.

The rock of this great intrusive sheet was classed by Macculloch as an "augite-rock,"‡ the augite being by far the most conspicuous mineral in it. A careful study of the large series of specimens brought from the islands shows that about one half of them should be classed as ophitic dolerites, and the other half as peridotites. But every specimen collected shows such variations owing to the

* Quart. Journ. Geol. Soc. vol. xxxiv. (1878) p. 677.

† I am greatly indebted to Dr. Taylor Smith for allowing me to study the whole of his specimens in connexion with my own.

‡ Western Isles of Scotland, vol. i. p. 439.

increase or decrease of felspar in different parts of the rock, that I can scarcely doubt of there being constant and insensible passages in the rock-mass from the felspathic dolerite to the non-felspathic peridotite.

The structure of the dolerites is exceedingly interesting; nowhere in the British Islands am I acquainted with more beautiful illustrations of the ophitic structure; the very similar dolerite which forms the great intrusive sheet at Portrush in Ireland comes nearest to it. The fractured surfaces of the rock exhibit the broad faces of black crystals of augite, occasionally interrupted by the enclosed felspar crystals. Under the microscope the augite, which by transmitted light is of a rich brown tint, is seen to form great crystals, the continuity of which is indicated by the persistency in direction of the cleavage-cracks, and by their uniform tint when viewed by polarized light. Within these broad crystals of augite are enclosed innumerable rectangular crystals of plagioclase felspar and rounded grains of olivine.

In the accompanying peridotites the felspar almost completely disappears. In some varieties, which may be classed as picrites, we find a number of broad crystals of augite which enclose numerous grains of olivine (see Plate XIII. fig. 4). In other cases the grains of olivine become so numerous as to make up the mass of the rock, and augite appears only occasionally in their interspaces. The latter variety may be classed with the dunites.

Under the microscope, the rich brown augite of the Shiant-Isles rock exhibits gas- and liquid-cavities along its planes of fracture and strain; but these are seldom filled with solid material, and the tabular inclusions producing Schillerization are, so far as my experience goes, never present in them. The augite of these rocks is seen in some cases to pass into paramorphic hornblende.

The olivine of these rocks is a very interesting mineral. In the thinnest sections it exhibits a distinctly yellow colour by transmitted light. This colour is nearly as intense as in the fayalite of the eulysite of Tunaberg, for an opportunity of studying which I am indebted to Mr. Thomas Davies, of the British Museum. This colour of the olivine is so marked and persistent that I can scarcely doubt of our having a highly ferriferous olivine associated with the dark ferriferous augite of the rock. As a rule, the minerals of the Shiant-Isles rocks are remarkably fresh and unweathered, but the olivine in some of the specimens, which were for the most part collected from fallen blocks washed by the sea, exhibits a very partial serpentinization. Enclosures with solid matter of black colour, and others containing liquids and gases occur along the planes of fracture; but the black stellate enclosures are rare. Occasionally, however, black or dark-brown enclosures are seen encroaching from the fracture-planes along planes parallel to the optic axis of the olivine grain, and so crowded together as to render the crystal black and opaque.

In addition to the non-felspathic rocks, which we have classed as

dunites, lherzolites, and picrites, we have the felspathic rocks which must be assigned to the troctolites (anorthite-olivine rocks) and the eucrites (anorthite-augite rocks).

The troctolites (forellensteins) in all cases exhibit intergrowths of felspar-crystals, forming a mass through which single grains or groups of grains of olivine are irregularly distributed (see Pl. XIII. fig. 5). Except in the perfectly fresh and unaltered condition of the minerals of which they are composed, and in their finer grain, these rocks exactly resemble in structure the well-known forellenstein of Volpersdorf.

The eucrites (anorthite-augite rocks) exhibit both the granitic and granulitic types of structure. An interesting example of the latter variety is illustrated in Pl. XIII. fig. 6.

The mass of basic and ultra-basic rocks in the island of Rum, which covers an area of from eight to ten square miles, and rises into a number of mountains varying from 2000 to 3000 feet in height, is made up principally of the minerals anorthite (or a felspar closely approximating in composition to that species), augite, and olivine. When all three are present, as is most frequently the case, we have an olivine-gabbro; when the first disappears we get a picrite, when the second is wanting we have a troctolite, and when the third is absent a eucrite. When both the first and second are wanting the dunites are formed; and the addition of the less abundant minerals, the enstatites, the biotites, and the spinellids, gives rise to lherzolites and other varieties. All these forms are found passing into one another by the most insensible gradations, and it would be possible, though, I think, most inexpedient, to propose names for other curious mineral combinations which occur here.

The Shiant Isles offer perfectly similar examples of transitions between these different types of basic and ultra-basic rocks.

Part II.

The Palæozoic Peridotites and Allied Rocks.

So far as is at present known, there are no peridotites of Mesozoic age in Scotland. The numerous masses of more or less altered ultra-basic rocks which are found scattered about the country, appear to have been formed during the Palæozoic epochs; but some of them may be of Archæan age. Certain of these old peridotites can, however, be proved to be of the age of the Old Red Sandstone and the Carboniferous.

At first sight the Palæozoic peridotites of Scotland appear to present the most striking contrast in their characters with those which we have been describing as belonging to the Tertiary epoch. But the more carefully we study these rocks, the more distinctly is it seen that the differences between the older and younger rock-masses are not essential but accidental ones,—the result of alterations which have taken place during the enormous periods of

time which have intervened between the eruption of the older and younger rocks respectively.

In the Tertiary peridotites the several minerals, olivine, enstatite, augite, picotite, &c., are perfectly fresh and unweathered; but in the Palæozoic rocks these minerals are represented, in most cases, only by their pseudomorphs; and it requires the most careful study to determine what was the nature of the original rock. When this is done, however, we are impressed by the conviction that in mineralogical constitution, as well as in structure, these Palæozoic peridotites present us with examples of all the varieties found among the Tertiary peridotites.

It may be convenient to apply distinct names to some of these much altered igneous rocks, just as it is admissible to term the indurated argillaceous sediments shales, while we call the less altered rocks clays. But it is a fact which cannot be too strongly insisted upon that when due allowance is made for the effects of alteration, operating during the enormous intervals of time which have separated the eruption of the Palæozoic and Tertiary peridotites, the agreement in all the *original* and *essential* characters between the rocks belonging to these widely separated periods is of the most complete character.

§ 1. Alteration of the Minerals in the Palæozoic Peridotites.

The most striking fact concerning the Palæozoic peridotites is that, as a rule, the whole of the original minerals of the rock have been converted into their pseudomorphs. The bulk-analysis of the rocks shows that they differ in composition from the Tertiary peridotites by the addition of water, and the diminution, to some extent, of the silica and certain of the bases. The olivines have been converted into serpentine; the enstatites are often represented by the same mineral or by steatite; the augites have become hornblendes, and the felspars have similarly been changed to zoisite and other minerals.

These changes are of a totally different kind from those which we have seen to affect the minerals in the more deeply seated eruptive rock-masses of the Tertiary period. Whether previously in their typical form, or in a more or less Schillerized condition, these minerals of the Palæozoic peridotites are equally affected by changes of a totally different character and origin. In some cases the change consists in the addition of water, and the conversion of an anhydrous silicate into a hydrous one. In other cases, the change appears to be a purely molecular one, the conversion of an unstable mineral into a stable one.

That these changes are produced at moderate distances from the surface where the minerals are affected by the percolation of atmospheric waters there cannot be any doubt. By the study of a sufficiently large series of specimens it can be shown that the changes in question have reached their maximum in those cases where the exposure of the rocks to atmospheric influences has been greatest, while more deeply seated portions of the rock remain comparatively

unaltered. Moreover, the change is, in many cases, seen to be set up from the surfaces or fissures of the minerals to which percolating atmospheric waters can most easily find access. It will be instructive to study the changes which the several minerals are found undergoing, under these circumstances, in the Palæozoic peridotites.

Olivine is the mineral in the peridotites which undergoes change most easily, and in almost every case it is found converted into serpentine; indeed it is quite rare to find examples of the unaltered olivine in these Palæozoic rocks. The occurrence of unmistakable pseudomorphs of serpentine after olivine, and the occurrence of particles of unaltered olivine in the midst of the serpentine masses, afford abundant evidence, however, of the fact that the serpentine is for the most part altered olivine.

When the olivine has undergone the changes described in the first part of this paper, and as a consequence contains stellate, tabular, and irregular enclosures of magnetite and other oxides, these are sometimes seen to persist after the hydration of the enclosing mineral. But the conversion of the olivine into serpentine, as is well known, is usually accompanied by a separation of magnetite, the silica combined with the iron of the original mineral being probably to some extent carried away in solution. In many cases it appears to be impossible to separate the mixed oxides formed during the Schillerization of the olivine from those liberated during its serpentinization.

The Rhombic Pyroxenes (*Enstatites*) undergo change much less rapidly than do the olivines. This is shown by the fact that in rocks which have originally consisted of olivine and enstatite, the former mineral is often entirely changed to serpentine, while the latter remains comparatively unaltered.

The change which the enstatites undergo seems to vary in different cases. Mr. G. H. Williams has described an interesting example of the direct conversion of a ferriferous enstatite (hypersthene) into a brown hornblende *. But of this kind of change I have not found any examples among the numerous enstatites of the Scottish rocks. On the contrary, the change in the mineral appears usually not to be a simply molecular alteration, but to be the result of hydration. Thus in the enstatite-basalt of a dyke at Carroch in Forfarshire, the fine crystals of highly ferriferous enstatite are found passing along their edges and fissures into a green substance undistinguishable from that found in similar situations in olivine crystals, and in some cases the whole crystal is converted into this substance. Again, in the serpentine dyke of the same district, the central and least altered portion consists of serpentine crowded with enstatite crystals, but in the more altered portions of the same mass, the enstatite is seen to pass into serpentine †.

* Amer. Journ. Sci. 3rd ser. vol. xxviii. (1884) p. 262.

† According to my own experience, the rhombic pyroxenes are generally converted into a serpentinous material, while the augites pass into a uralitic substance or directly into hornblende; and I would venture to suggest that the crystals which Mr. Williams describes as changing into hornblende, in the passage referred to, may be pseudo-hypersthene, and not true hypersthene.

When the enstatite has been previously Schillerized, the characteristic enclosures often persist after the serpentinization of the material in which they are enclosed. We may thus sometimes infer the former existence of a particular mineral in a rock by the presence of the characteristic enclosures of the mineral in the midst of its alteration-products.

The Monoclinic Pyroxenes (*Augites*) usually undergo only the molecular change by which they pass into hornblendes. Thus crystals of the dark brown ferriferous augite of the Shiant-Isles rock are seen passing into dark-brown hornblende with the characteristic pleochroism and cleavage of that mineral. It is worthy of notice, as pointed out by Williams *, that in these cases of the conversion of a pyroxene directly into hornblende the principal planes of the two minerals are parallel, and even the planes of twinning of the original may persist as such in the altered form †.

When augite has been submitted to Schillerization before alteration the results are of a very different kind, as is so well seen in the saussurite-gabbros or wurlitzites. By the collection of the iron of the mineral into the enclosures a substance is left which has the composition and optical properties of diopside, and this is altered into the green varieties of hornblende known as smaragdite and actinolite, while the separated iron-oxides crystallize by themselves.

On the alterations by weathering of the felspars and other accessory minerals of the peridotites it will not be necessary to dwell in detail, as they are not essential minerals of the peridotites.

§ 2. Varieties of the Palæozoic Peridotites.

Of all the varieties of the peridotite which we have described as occurring among the intrusive rocks of Tertiary age, representatives are found among the more or less altered Palæozoic igneous masses.

Rocks like the dunites, which are composed almost entirely of olivine, are by hydration converted into serpentine, and some of the very pure serpentine masses of Scotland were in all probability originally dunites.

But since enstatite, as we have already seen, is, like olivine, also converted into serpentine, though somewhat more slowly, masses of pure serpentine may be formed by the hydration of olivine-enstatite rocks like lherzolite.

Admirable examples of such altered olivine-enstatite rocks have been described by Professor Bonney as occurring not only at the Lizard in Cornwall but at Colmonell in Ayrshire ‡. My own examination of slices taken from this serpentine leads me to conclusions

* Amer. Journ. Sci. ser. 3, vol. xxviii. p. 264.

† In some cases this conversion of augite into hornblende takes place directly, the dichroic hornblende appearing, as it were, eating into the non-dichroic augite. But in other cases the whole augite crystal appears to be converted into uralitic and fibrous hornblende, and this may change subsequently into common hornblende.

‡ Quart. Journ. Geol. Soc. vol. xxxiv. (1878) p. 769.

identical with those arrived at in this paper concerning the rocks in question.

An equally striking example of a rock of the same class occurs in Forfarshire, near the town of Kirriemuir. This rock was described in the year 1825 by Sir Charles Lyell, after studying it with the assistance of Dr. Buckland, as a mass of serpentine forming a dyke which intersects the Old Red Sandstones and contemporaneous volcanic rocks of the district *. In 1875 I had the advantage of studying this mass of serpentine under the guidance of Sir Charles Lyell. The dyke of serpentine can be traced running for a length of at least 14 miles, in an E.N.E. and W.S.W. direction, near the southern foot of the Grampians, and parallel to that range; it is well exhibited in several deep cavities, cut by streams descending from the mountains, especially those of the Carity, the Prosen, and the South Esk. The dyke varies in width at different points from 100 to 300 yards; it encloses "horses" or masses of the rocks traversed by it, and is itself intersected by other intrusive rocks. It produces marked alteration on the rocks which it traverses †.

At its sides the rock is a mass of serpentine, traversed by numerous veins of chrysotile and exhibiting no evidence of the minerals of which the rock was originally formed. But towards the centre, crystals of "Schiller spar" make their appearance, and the serpentine gradually passes into a hard crystalline mass which Lyell compared with the rock of the Cuchullin Hills, and called hypersthene-rock.

Studied by the aid of the microscope, this central and least weathered part of the dyke is seen to be made up of serpentine, clearly pseudomorphous after olivine, and containing large crystals of a ferriferous enstatite in a more or less advanced stage of alteration into bastite and serpentine. In some portions of the central mass of the dyke the ferriferous enstatite prevails almost to the exclusion of the olivine, and we have a rock strikingly resembling the bronzite-rock of the Kupferberg, near Bayreuth, and of St. Stephan in Upper Styria (see Pl. XIII. fig. 7). This is a type of rock which has not, I believe, been hitherto recognized in the British Islands. As we trace the rock outwards from the central mass, the alteration becomes greater, till at last all traces of the individual enstatite-crystals disappear, and we have a serpentine in which no vestige of the original mineral constituents of the rock can be distinguished. Among the dykes which intersect the great serpentine-mass, I found one to consist of a coarse dolerite or augite-gabbro, while another is a very beautiful example of a hypersthene- (ferriferous enstatite) dolerite.

The serpentines with altered bronzite, from the neighbourhood of Aberdeen ‡, are also altered olivine-enstatite rocks.

When the older peridotites contain a considerable proportion of

* Edinb. Journ. of Sci. vol. iii. (1825) p. 112.

† I am much indebted to Leonard Lyell, Esq., F.G.S., of Kinnordy, for several interesting series of specimens which he has sent me from this district.

‡ See Heddle, Mineralog. Mag. vol. v. pp. 4–6.

augite, this mineral remains enclosed in the serpentine, or is converted into hornblende. In the latter case we have a rock of the same class as that described by Professor Bonney, from North Wales and the Lake district *, as hornblende-picrite. Two examples of such altered picrites have been described in the neighbourhood of the Firth of Forth.

The picrite which forms an eminence on the S.W. of the island in the Firth of Forth was discovered by Mr. Adie, and described first by Dr. A. Geikie †, and subsequently by its discoverer ‡. The rock may be classed with the picrites, though it sometimes contains a not inconsiderable proportion of felspar. It is an interesting circumstance that the olivine of this rock is sometimes only slightly serpentinized. The augite is sometimes quite intact, but is sometimes seen passing into brown hornblende. Some of the hornblende of this rock, however, may be original. The association of augite, hornblende, and biotite in the rock is of the closest kind, but it is difficult to say whether this association, in certain cases, should be interpreted as due to intergrowth or to paramorphic changes. I have been kindly supplied by Mr. T. Waller, of Birmingham, with the following analysis of this beautiful rock:—

Silica	37·8
Alumina	9·7
Ferric oxide	3·4
Ferrous oxide	7·0
Lime	4·1
Magnesia	22·9
Soda (with trace of potash)	0·8
Loss on ignition	14·0
	99·7

As leucoxene occurs among the alteration-products in the rock, titanic acid is certainly present; it was not, however, specially determined in the analysis, and it has therefore been included in part with the silica and in part with the alumina.

The specific gravity of this rock is 2·81.

The picrite of Blackburn, near Bathgate §, which has also been described by Dr. A. Geikie, resembles that of Inchcolm in its mineralogical constitution, but is of especial interest to geologists on two grounds. If the interpretation given of the relations of this rock be a correct one, it affords an example of an ultrabasic rock occurring as a lava-stream, and at the same time illustrates the possibility of the heavier minerals in a lava sinking to the bottom of it, so as to cause the lower portions of the stream to be of more basic character than its upper part.

There is one of the older peridotites of Scotland, however, which

* Quart. Journ. Geol. Soc. vol. xxxvii. (1881) p. 137, and xxxix. (1883) p. 254.
† Trans. Roy. Soc. Edinb. vol. xxix. (1880) pp. 507, 508.
‡ Cole's Studies in Microscopical Science, vol. i. (1882) p. 45.
§ Trans. Roy. Soc. Edinb. vol. xxix. (1880) pp. 504–507.

presents so many peculiar characters that it appears to me to be worthy of special description. In some respects it appears to differ from any rock of the class that has previously been described.

§ 3. The Scyelite (altered Mica-Hornblende-Picrite) of Caithness.

This rock is of so remarkable a character and affords so many striking illustrations of the principles enunciated in the foregoing pages, that a detailed description of it seems to be called for.

It occurs as a boss rising above the thick mass of glacial gravels on Achavarasdale Moor, situated in the Reay country in the west of Caithness, near to where that county borders on Sutherland. It appears first to have attracted attention about fifteen years ago, when Sir Robert Sinclair and Mr. Tait noticed its peculiar appearance, and brought specimens of it to Thurso to submit to the late Robert Dick.

Mr. David Gunn, of Thurso, and Mr. John Gunn, of Dale, near Halkirk, have taken much interest in this peculiar rock and its surroundings, and have sent specimens of it to different museums and to geologists in various parts of the country. To the former gentleman I am indebted for a carefully constructed plan, showing the dimensions and positions of the singular rock-mass, with a series of specimens taken from different parts of it; to the latter I am under the very greatest obligation for specimens of the material in the best state of preservation and for much valuable information collected with much care and patience.

The boss of highly glittering rock, which is said to rise about 10 feet above the general level, is about 9 yards long from S.W. to N.E. and about $7\frac{1}{2}$ yards broad from N.W. to S.E. It is surrounded by a mass of disintegrated fragments derived from the same rock, which extends over a nearly circular area about 25 yards in diameter; excavation to the depth of 5 feet in this disintegrated material failed to reach the solid rock. The bright silvery scales so abundant in the rock and the soil derived from it, together with the covering of grass with which it is clothed, make the boss a very conspicuous object in the midst of the heath-covered moor. Prof. Heddle states that the rock which surrounds the boss on all sides is a "syenitic gneiss;" but owing to the thick covering of drift-gravel the actual junction between the two rocks has not been reached in any of the excavations that have been made.

Carefully selected specimens of the rock were sent to Mr. Hugh Robert Mill, B.Sc., F.I.C., and by him were submitted to chemical analysis in the laboratory of the University of Edinburgh. I have that gentleman's permission to publish the results which he obtained. Three more or less complete analyses of the rock were made, giving the following results:—

	I.	II.	III.
Silica	41·74	42·17	42·04
Total iron as ferric oxide	11·58	10·36	10·92
Alumina	3·08	3·97	3·48
Magnesia	26·83		30·65
Lime	4·75		3·77
Manganous oxide	·70		
Soda and potash	4·85	1·90	
Water and carbonic acid	7·78	7·19	7·67
Ferrous oxide	3·63	2·01	2·40

From a discussion of the results which the analyst considered most reliable, he gives the following as the composition of the rock:—

Silica	42·10
Alumina	3·28
Ferric oxide	8·27
Ferrous oxide	2·13
Manganous oxide	·70
Lime	3·77
Magnesia	30·65
Soda and potash	1·90
Water and carbonic acid	7·73
	100·53

The specific gravity of the rock was determined for me by Mr. Grenville Cole on the least altered specimen I could procure, and proved to be 2·82.

The proportions of silica, alumina, magnesia, and water indicate that the rock belongs to the class of the ultrabasic rocks, and that it is in an altered and hydrated condition.

The macroscopic appearance of this rock is very peculiar. It most nearly resembles some of the so-called "Schiller-spars," especially the paler varieties known as diaclasite; but closer examination shows that, as Prof. Heddle pointed out, it is a perfectly unique rock.

The most conspicuous mineral in the rock has a micaceous appearance, with a pale bronzy-yellow colour and a submetallic lustre. The rock breaks in large flat planes, along the cleavage of this mineral, and in some cases these planes of fracture cut one another at such sharp angles as to give the impression that the rock is made up of a number of large prismatic crystals. At the request of Mr. L. Fletcher, to whose advice and assistance I am greatly indebted in connexion with these studies, Mr. Miers, of the Natural History Museum, made a series of measurements with the contact goniometer, the results of which were so discordant as to prove that these planes are neither crystal-faces nor planes of cleavage. The conclusion was confirmed by the study of large sections of the rock, which show that the micaceous mineral lies in different positions within each of the pseudo-crystals.

Prof. Heddle regarded the micaceous mineral as talc *, and he states that the rock is made up of that mineral, with augite, some

* Mineralogical Magazine, vol. v. (1884) p. 260.

serpentine, and magnetite. But while the hardness of the micaceous mineral is very variable, depending on the extent of alteration it has undergone, I found it, in fresh specimens, to be no less than 3 of Mohs' scale. The specific gravity was determined, by taking the density of a solution of the boro-tungstate of cadmium, in which particles of the mineral remain just suspended, to be 2·8; examined with the blowpipe it is found to be extremely infusible, only the very thinnest splinters showing traces of whitening and fusion on the edges after prolonged action with a powerful flame. In the blowpipe-beads it gave a faint iron-reaction. It is scarcely acted upon at all by either boiling hydrochloric or sulphuric acid.

The general appearance and many of the properties of this mineral so strongly resembled those of the altered enstatites (diaclasite or bastite, &c.) that I was for some time inclined to refer it to one of those species. This conclusion appeared to be confirmed by a study of slices under the microscope; for while its extinction appeared to be that of a rhombic mineral, it was seen to contain great numbers of tabular inclusions, like those found in, and often regarded as characteristic of, enstatite, bronzite, and hypersthene. A thin flake of substance which was examined by Mr. Fletcher in a polariscope with convergent light seemed to indicate that the mineral is a uniaxial one, however, and I accordingly determined to attempt to isolate the mineral and submit it to analysis.

The isolation of the mineral proved, in this case, to be a task of considerable difficulty. From the powdered rock the magnetite and the minerals which adhered to it were removed by an electro-magnet. The irregular grains of serpentine, it was found, could be separated from the flaky particles of the micaceous mineral and of hornblende by repeated washings in water. But the latter two minerals were found to be only very imperfectly separated, owing to their similar density, by the boro-tungstate solution; and enough material for a partial analysis could in the end be only obtained by laborious picking under the microscope. I am greatly indebted to my assistants in the geological laboratory of the Normal School of Science, Mr. G. Cole and Mr. W. Atkinson, for the patience and care with which they carried out this process of separation and the subsequent chemical operations. These operations were necessarily performed upon extremely small quantities of material, so that the results obtained from the several different determinations did not show a very close agreement. They were, however, sufficient to prove that the mineral had a composition which may be approximately represented as follows:—

Silica	38·0
Alumina	13·0
Iron oxide calculated as ferric oxide	4·5
Lime	5·0
Magnesia	24·0
Water	6·5
Alkalies ? by difference	3·0

It will be observed that this analysis differs from that of biotite, the only uniaxial mineral which suggests itself for comparison, by the low proportion of ferric oxide (which is only to some extent compensated for by the higher alumina-percentage), by the large proportion of lime and water, and the probably low percentage of the alkalies.

Under these circumstances it became necessary to make as accurate an examination of the optical properties of the mineral as was possible, and in doing this I had the great advantage of the advice and assistance of Mr. L. Fletcher. Flakes of the mineral were mounted in Canada balsam, and examined by means of a microscope constructed by Nachet, of Paris, on the pattern described by MM. Fouqué and Michel Lévy*. This microscope has the great advantage of permitting the interference-figures, exhibited by the polariscope with the converging system of lenses of Bertrand and von Lasaulx, to be examined even with the highest powers. We found in this way that not only was the mineral practically uniaxial, but that even when compared with other so-called uniaxial crystals, like the Vesuvian meroxene, for example, the interference-figures indicate an excessively small axial angle. The only mica with anything like so small an axial angle which we were able to find was a remarkable pale-coloured, silvery biotite from Easton, in Pennsylvania, which does not appear to have been analyzed, though its optical characters have been described by Blake†.

In the determination of the other minerals in the rock, far less difficulty was experienced.

The most abundant constituent of the rock, as seen in thin sections under the microscope, was found to be a green hornblende. In the greater part of the rock the characters of this mineral were clear and unmistakable. By transmitted light its colour is a very pale green, and its pleochroism, though distinct, was by no means vivid. Basal sections afforded the means of measuring the angle of the principal cleavages as exhibited in well-marked cleavage cracks, and left no doubt as to the species of the mineral, and this is confirmed by its extinction-angle. In many places the hornblende is very clear and fresh-looking, and free from inclusions of all kinds except the grains of magnetite scattered through it. But in places this pale green mineral exhibits traces of the peculiar tabular inclusions of diallage, and in such portions of the crystals the extinction-angle indicates that we are dealing with an augite rather than with a hornblende. The conclusion to which I am led by the study of a large series of preparations of this rock is, that the mineral was originally augite, that it was by Schillerization converted into diallage, and that subsequently this diallage was amphibolized. In many slices of the rock, however, the mineral is a perfectly clear and fresh-looking hornblende, and exhibits no trace of its secondary origin.

Enclosed in the hornblende, and often penetrating into its fissures,

* Minéralogie Micrographique (1879), p. 27.

† Amer. Journ. Sci. vol. xii. (1851) p. 6.

is a dark-green serpentine. Examined with high powers of the microscope, this serpentine is seen to be filled with black and brown enclosures, some rod-like and stellate in form, others of a tabular character. Sometimes these inclusions are arranged in one set of parallel planes only; in other cases they lie in two sets of planes intersecting one another. There can be no doubt that much of this serpentine is pseudomorphous after olivine; but some of it may replace enstatite.

The micaceous mineral presents very different conditions in different portions of the rock. Most frequently it appears to have been changed into a creamy yellow, amorphous substance, which by polarized light shows all the characters of an alteration-product; but in the fresher examples of the rock it exhibits the peculiar outlines and the strong basal cleavage of a mica. From ordinary biotite, however, it is distinguished at once by its pale colour, a faint buff-yellow, and its feeble pleochroism, which is, however, sufficiently well marked to be unmistakable. In places the fresher part of this mineral is rendered black and almost opaque by the abundance of tabular inclusions which it contains; these appear to be arranged in planes parallel with the basal plane, that is to say in the direction of the principal cleavage. The distribution of these inclusions is strikingly local, some parts of the mica crystals being almost entirely free from them, while in adjoining portions they have become so frequent as to entirely destroy the translucency of the crystal.

Small grains of magnetite are found scattered through all the minerals of the rock; but of accessory minerals there are only a few traces. Very rarely indeed could any minerals be detected which might be regarded as alteration-products of felspar.

By drawing, with the aid of a camera-lucida, the outlines of the crystals in a section of the rock, and cutting out and weighing the fragments of paper representing each mineral, an estimate was formed of the proportions which the several minerals bore to one another in the rock. The operation, repeated in the case of a number of sections, so as to afford a good general average, gave the following percentages:—

Hornblende	58·5
Serpentine	22·0
Altered mica	18·5
Magnetite and accessory minerals	1·0

This result appears at first sight very different from what might be expected from a macroscopic inspection of the rock, which would lead one to regard the conspicuous mica as the predominant constituent. But minerals with a strong cleavage like mica are very apt to make a much greater show on fractured rock-surfaces than their actual abundance in the rock entitles them to do.

The microscopic structure of the rock is a very marked one. The hornblende-crystals enclose rounded grains of serpentine and crystals

of mica. The hornblende occupies precisely the same relation to these minerals as the augite does to the olivine in the peridotites of the Shiant Isles. The structure of the scyelite is therefore distinctly ophitic.

The study of this rock leads to the conclusion that, in spite of the clear and fresh appearance of most of the minerals of which it is made up, they are all of secondary origin.

The hornblende is a paramorph after augite, some at least of which had been previously converted into diallage. Very similar hornblende occurs in some examples of the picrite of Schriesheim, and this rock exhibits, as Professor Bonney observes, every gradation from augite to hornblende *.

The serpentine of the rock clearly replaces olivine, and in some cases probably enstatite also, as is indicated by the peculiar nature of the enclosures, which often persist and retain their form after the hydration of the enclosing mineral.

Whatever the micaceous mineral should now be called, it appears to have been originally a highly magnesian biotite, that is to say an approximately uniaxial mica. Its pale colour and feeble pleochroism appear to be clearly related to the low percentage of iron which it contains.

Another peculiarity in this mica is probably the replacement of much of the alkalies by basic water. How far these peculiarities of the mineral are original, and how far they are of secondary origin, it may be difficult to determine. The abundant tabular enclosures in the mineral point to the conclusion that Schillerization, or the dissolving-out of the iron and its collection into the hollows of negative crystals, has gone on to a considerable extent. It was probably at the first a biotite, very rich in magnesia and poor in iron, with the potash largely replaced by basic water; but some of the iron and the alkalies have not improbably been removed during the process of Schillerization.

That such biotites with a low percentage of iron not unfrequently occur in the ultra-basic rocks is highly probable. I have found a mica similar to that of the scyelite in several altered peridotites, among others some varieties from Schriesheim. The mineral may easily be mistaken for an altered enstatite, from its optical properties.

Dr. Heddle has analyzed a mineral occurring in the serpentine of Milltown, Glen Urquhart †, which appears to be analogous to the biotite of the scyelite. The mineral is stated to be pale green or nearly white in colour, to have a specific gravity of 2·781, and to be associated with large pale crystals of hornblende.

The analysis is as follows:—

* Quart. Journ. Geol. Soc. vol. xxxix. (1883) p. 256. [Professor Cohen has recently pointed out that the mineral formerly taken for diallage in the Schriesheim picrite is really hornblende (Neues Jahrb. für Min. 1885, vol. i. p. 242).]

† Trans. Roy. Soc. Edinb. vol. xxix. (1880) p. 18.

Silica	40·307
Alumina	12·582
Ferric oxide	1·809
Ferrous oxide	3·335
Manganous oxide	0·384
Lime	7·581
Magnesia	21·000
Potash	6·561
Soda	0·953
Water	5·738
	100·250

The small proportion of the iron-oxides and the quantity of lime suggest a resemblance to the mineral of the scyelite. This pale-coloured mica is said to pass into a lustrous brown variety of ordinary biotite, containing 4·913 per cent. of ferric oxide and 19·802 of ferrous oxide.

Nowhere perhaps would it be easy to find a better example of the different changes to which the minerals of igneous rocks are subject. If our interpretation be correct, the scyelite was originally a picrite with well-marked ophitic structure, made up of augite, enclosing and intercrystallized with grains of olivine, with some enstatite, to which was added a considerable quantity of a highly magnesian biotite.

The first change to which this rock was subjected was clearly due to deep-seated action, and resulted in the conversion of a part, at least, of the augite into diallage, in the development of tabular and other enclosures in the olivine and enstatite, and in a similar change in the biotite.

Subsequently to this, and under totally different conditions, a new set of changes was brought about in the rock. The augite was converted into hornblende, the olivine and enstatite into serpentine, and the mica became more or less hydrated, losing in some parts of the mass its physical and optical properties. Yet during all these changes the form and relations of the original minerals were not destroyed, and in the later alterations the structures produced by the first set of changes were so far spared as to admit of our deciphering the history of this singular rock.

Summary of Results.

From the observations described in the preceding pages, it appears that many rock-forming materials may be made to assume new and unfamiliar aspects by the development of enclosures along certain planes within their crystals. In this way the augites are converted into diallages and pseudo-hypersthenes, and the ferriferous enstatites into bronzites and the varieties to which the name of hypersthene was originally applied; similarly, olivine passes into a black, opaque, fissile mass, which has frequently been taken for magnetite, and the felspars acquire avanturine and *chatoyant* characters. For the process

by which this change has been brought about, the name of "Schillerization" is proposed, and diallage and common hypersthene are shown to be Schillerized forms of augite and ferriferous enstatite respectively. In the case of some minerals, and notably the rhombic pyroxenes, the altered forms are much more familiar to mineralogists than the unaltered.

The enclosures which exist in these Schillerized minerals, giving rise to their peculiar colour, lustre, and sheen, are of the nature of negative crystals, more or less completely filled with products of decomposition, such as hydrated silica and hydrated ferric oxide. When these isotropic mixtures fill the whole cavity of the negative crystal, the enclosures appear to have definite crystalline forms; in many instances, however, they form patches with more or less irregular outlines, partially filling the hollow of the negative crystal; and sometimes the crystalline forces have come into play and have caused them to assume "dendritic" forms within the cavities where they are deposited. These negative crystals, with their contents, vary greatly in size, from objects visible to the naked eye down to such as can only just be recognized by the highest powers of the microscope, while there are probably others which are ultramicroscopic in their dimensions.

The production of the Schillerized condition in minerals is shown to be related to the depth at which the crystals have originally existed in the great central cores of the Hebridean volcanoes. The Schillerized forms of the minerals are only found in deep-seated intrusive rock-masses; but the converse of this statement is not true, for in deep-seated rocks this change is sometimes evidently local, and some of the crystals may have altogether escaped it. The degree of Schillerization increases also with the depth at which the rock has existed.

An efficient agent for the production of this Schillerization, that is the formation of negative crystals and their more or less complete infilling with decomposition-products, is pointed out in the solvent action of heated water and other fluids acting under great pressure.

This solvent action takes place most readily along certain planes within the crystal, and these directions of greatest susceptibility to chemical action differ from those of easiest fracture (cleavage-planes); the positions of such planes are perhaps also dependent to some extent on twin-structure, facts for which we were prepared by the closely related phenomena of the *Aetzfiguren*. We have here, in fact, the phenomena of the *Aetzfiguren* seen in three dimensions—that is to say, displayed in a solid instead of on a surface.

In some cases the secondary products contained in the negative crystals seem to be derived from the mineral in which the hollows occur; in other cases, as in the felspars, it is clear that they must have been, in part, brought from outside the crystals affected.

The partial solution of minerals which results in the formation of negative crystals within them often brings about great changes in the colour, in the pleochroism, and in the positions and relations of the optic axes of the original crystals. It is probable that the iron-

silicates are among the first to be attacked by the solvent agents, and the products formed by their decomposition are the first to be deposited within the negative crystals.

To the same cause, the presence of water and other liquids under pressure, we must assign the formation of a network of cavities along fissures of the crystals of rock-forming minerals, these cavities containing, in some cases, liquids with bubbles, and in others solid substances which have crystallized within them.

While these networks of cavities sometimes lie along actual fissure-planes in the crystal, in many other cases they form bands traversing the crystal where no actual rupture can be seen to have taken place. These bands of cavities probably indicate portions of the crystal which have been in a condition of intense strain, along which, according to a well-known physical law, solvent agencies operate with greater force than elsewhere. The same band of enclosures (marking a plane of strain) is often found traversing a number of adjoining crystals in a rock.

The change by which certain felspars acquire their beautiful play of colours is analogous to that by which the avanturine appearance, or Schiller, is acquired; but the former alteration appears to be an ultramicroscopic one. It probably consists of the development of thin plates of hydrous silica in a set of parallel planes within the crystal. Like the Schiller structure, it is characteristic of minerals which have formed parts of deep-seated rocks.

The twin-lamellæ found in most plagioclase felspars appear not to be necessary and original structures of the crystals, but to have been developed in them by strain, like the similar twin-lamellæ in the rock-forming calcites. While some of these twin-lamellæ are probably produced by the stresses and strains set up during the cooling of a crystal after its first formation, as was illustrated experimentally by Foerstner, others among them are clearly of long subsequent date to the consolidation of the rock, and have been developed by the mechanical forces which have affected the whole rock-mass leading to the formation of cracks in the crystals which compose it.

By Schillerization the most striking *mimicry* of one mineral by another may be produced. Thus the first stages of the Schillerization of the monoclinic and rhombic pyroxenes are diallage and bronzite respectively, minerals which have been constantly mistaken for one another; by a further change the same minerals may in turn pass into pseudo-hypersthene and true hypersthene, minerals which present the most striking similarity in their colour, lustre, and also in their general aspect, when viewed in thin sections, and can only be distinguished by their optical properties.

All the minerals, whether in their normal form or in their Schillerized condition, may be converted into their pseudomorphs; and this change is not always a molecular one only (paramorphism), but is sometimes accompanied by hydration due to the action of water penetrating from the surface or by other changes in their composition. Under such conditions augite is converted into hornblende,

enstatite into bastite, and olivine into serpentine. These changes, which are quite distinct in their nature and their origin from Schillerization, may be greatly modified, however, by the alteration, due to deep-seated action, which the minerals have previously undergone.

As diallage is only an altered form of augite, it is impossible to maintain as a separate class rocks whose only distinction is the presence of that variety. Hence, as many petrographers have admitted, it becomes difficult to accept the mineralogical distinction between gabbro and diabase. The name gabbro is so convenient, that its retention is advocated for all the most perfectly holocrystalline (granitic) varieties of basic rocks, whether the augite is in its normal condition or its Schillerized form (diallage). The name diabase may be more conveniently employed for altered forms of dolerite.

In many cases the process of Schillerization has resulted in the conversion of the olivine into a black and opaque substance, often mistaken for magnetite. Many of the gabbros supposed to contain no olivine in reality have their olivine in this curiously altered state. The class of the olivine-gabbros is much larger than is usually supposed, and the group of gabbros without olivine is proportionally restricted.

It has been shown that in the Western Isles of Scotland there exists a series of ultra-basic rocks of Tertiary age which exhibit all the essential features of the ultra-basic rocks of pre-Tertiary age, and like them may be classed under the varieties of dunite, lherzolite, picrite, eucrite, and troctolite. These rocks are most intimately associated with the gabbros and dolerites of the district, an association which finds an exact parallel in the case of their older representatives.

The study of the remarkable changes which the minerals of these rocks undergo, as they are traced to successive depths from the original surface, is greatly facilitated by the fact that, in consequence probably of the late period of their eruption, they have suffered but little from agents acting from the surface. In many cases the felspars exhibit no trace of kaolinization, the augites are fresh and show no signs of uralitization, and the olivines are not in the least serpentinized; thus the changes which are due to the action of deep-seated waters are not in the least degree complicated with, or concealed by, alteration of a totally different character and origin.

But in the masses of peridotite of Palæozoic age which are scattered about Scotland quite opposite conditions prevail. The dunites are converted into serpentine-rock, the lherzolites into bastite-serpentine, the enstatite-rocks into bastite-rocks, and the augite-picrites into hornblende-picrites. But, in all these cases, a careful study of the altered materials shows that originally they were identical in mineralogical constitution and in structure with the peridotites of Tertiary age.

In the scyelite of Caithness we have a very interesting example

of an ultra-basic rock of a new and hitherto undescribed type. It was originally a mica-picrite with strongly marked ophitic structure, and exhibits evidence of some of its minerals having undergone Schillerization; but at the present time all the original minerals are represented by their pseudomorphs—augite by hornblende, olivine and enstatite by serpentine, and biotite by a curious hydrated form of that mineral.

The recognition of certain characters in the rock-forming minerals as being original and essential, and the distinction of such from other characters which are secondary and accidental, is of the highest importance to the petrographer and geologist, and not less so to the mineralogist.

Rightly studied, these minerals are capable of furnishing the geologist with evidence not only concerning the mode of origin of the rocks of which they form a part, but also of the changes which they have undergone since their first formation. The study of the minerals included in the crystalline rocks is not less important than that of fossils in the sedimentary rocks. And to the mineralogist the study of the secondary characters of minerals, and of the causes which have produced them, is equally necessary. Researches of this kind, indeed, can scarcely fail in the end to reduce many so-called mineral species to the rank of accidental, though still highly interesting, varieties. But of still greater importance is the recognition of the fact that the investigation by the aid of the microscope of the processes by which minerals have acquired their several characters, and the consequent tracing of the evolution of mineral species and varieties, is calculated to raise mineralogy from its present rank as a merely classificatory science, to infuse it with new life, to open out to it new realms of research, and to invest it with a higher importance than is at present accorded to it in the family of sciences.

EXPLANATION OF PLATES X.–XIII.

Plate X.

[Note.—Some of the details of these figures can only be distinctly seen by employing a low-powered magnifier.]

Fig. 1. A crystal of felspar from a gabbro-vein traversing dunite at Scuir na Gilean, Isle of Rum, viewed by polarized light with a magnifying-power of 35 diameters. This crystal admirably illustrates the conclusion that the lamellar twinning must be regarded as a *secondary* character of the plagioclase felspars. A large portion of the crystal is quite free from any trace of the lamellar twinning. The crystal is traversed by a number of cracks, and between the cracks, lamellar twinning is seen in some cases to be developed. An examination of the relations between the fissures and the lamellar twinning is conclusive as to the non-existence of many of the twin-structures before the formation of some of the fissures which traverse the crystal. This section also illustrates the manner in which lamellar twinning is frequently developed along two different sets of planes in plagioclase felspar, and that these two sets of twinnings sometimes intersect one another. The way in which these twin-lamellæ are found starting irregularly at certain points in the crystal, and dying away

in the untwinned portions, like the similar twin-structures artificially produced in calcite, is also seen. Some of these twin-structures may have been developed by the strains set up in the cooling-down of the crystal, others were probably induced by the movements in the rock-mass which produced the fissures in the crystals that built it up. (See pages 364–366.)

Fig. 2. Section of felspar in troctolite from Halival, Isle of Rum. Magnified 225 diameters. This crystal exhibits the *first stages* of alteration in the felspars. It is traversed by numerous cracks, and along these, as well as in other parts of the crystal, many liquid- and gas-cavities have made their appearance. Some of these cavities, which are of considerable size, are particularly interesting from the fact that they are seen by their regular forms to be *negative crystals*. In some cases the infilling of these cavities with solid substances has clearly commenced. (See pages 375, 376.)

3. Section of felspar from the olivine-gabbro of Loch Coruiskh, Isle of Skye. Magnified 225 diameters. This felspar is in a more advanced state of alteration. The cavities lying along lines of fissure or strain are much more numerous and are in almost all cases filled with dark-coloured products of decomposition. In addition, we see the first traces of very minute dark-coloured tabular enclosures (negative crystals filled with decomposition-products) making their appearance along one set of parallel planes within the crystal. (See page 376.)

4. Section of felspar from the olivine-gabbro of Ardnamurchan. Magnified 225 diameters. This section shows bands of cavities, some of which are partially filled with solid materials, and *two* series of tabular enclosures (infilled negative crystals) arranged in two sets of parallel planes which intersect one another nearly at right angles. (See page 376.)

5. Another section of felspar from the same rock as the last, showing the enclosures arranged in two sets of planes, as in the former example, with the addition of a *third* series intersecting them. This section is also magnified 225 diameters. (See page 376.)

6. Section of felspar from the olivine-gabbro of Loch Coruiskh. Magnified 225 diameters. This shows irregular enclosures filling cavities which lie along cracks and scattered irregularly through the crystal; also tabular enclosures arranged along no less than *five* different intersecting planes in the crystal, namely, two pinacoidal, two prismatic, and one basal. The first four are seen in section, the last in plan. Besides these there are cloudy patches in the crystal, which the highest powers employed are only partially capable of resolving into similar but much more minute enclosures. (See page 376.)

7. Section of an excessively altered crystal of felspar from the olivine-gabbro of Ardnamurchan. Shown with a magnifying-power of 225 diameters. The whole of the felspar exhibits a rich brown tint from the abundance of foreign enclosures which have been developed in it. These enclosures form nebulous-brown patches, which, with the very highest powers of the microscope, can only be partially resolved into irregular solid particles lying in cavities of the crystal, and tabular or bacillar enclosures, filling negative crystals and developed along a number of planes within the felspar. In other portions of the section, the enclosures are sufficiently large to be rendered visible by the power employed. A further concentration of the decomposition-products has taken place in places, leading to the formation of dendritiform accumulations of the iron-oxides, &c. Although the crystal is so greatly altered, the characteristic lamellar twinning can be observed in certain portions of it with the aid of the polariscope. This lamellar twinning has evidently influenced the action of the solvent forces in eating out negative crystals along certain planes, and in infilling them with decomposition-products. This example affords an easy transition to the *chatoyant* felspars, in which the secondary structures are *ultra*-microscopical. (See pages 376, 377.)

Plate XI.

Fig. 1. Fissures and incipient fissures in the very fresh brown augite of the ophitic dolerite from the Shiant Isles, showing the development of a reticulation of cavities along the lines of fracture and strain within the crystal. Most of these cavities are empty, or contain liquids in which bubbles may sometimes be discerned; but a few of them appear to be filled with solid substances. These cavities are very minute; they are shown as seen with a magnifying-power of 500 diameters. (See page 378.)

2. More altered brown augite from the picrite of central Rum. The cracks and bands indicating strain are more numerous than in the last example, and are marked by lines of cavities of much larger dimensions, the cavities being in almost all cases filled with solid decomposition-products which are dark-coloured and opaque. The section is shown as displayed by a magnifying-power of 75 diameters. (See page 378.)

3. Two crystals of augite from the olivine-gabbro of Loch Coruiskh, Isle of Skye, showing the conversion, to a different extent in the two cases, of this mineral into diallage. The action by which enclosures are developed along planes parallel to the orthopinacoid is clearly seen to be set up from the *outer surface* of the crystal. The central parts of the crystal have all the characters of ordinary augite, while the peripheral portions are converted into true diallage. The objects are figured as seen with a magnifying-power of 50 diameters. (See page 379.)

4. Crystal of true diallage (foliated augite) from the olivine-gabbro of Beinn More, Isle of Mull. At one end of the crystal the development of another series of enclosures along the clino-pinacoid has commenced, converting the crystal into pseudo-hypersthene. Seen as magnified 100 diameters. (See page 379.)

5. Portion of crystal of augite from the olivine-gabbro of Loch Coruiskh, Isle of Skye. This example shows that the development of enclosures takes place most abundantly along lines of cracks and in their immediate vicinity. Two sets of enclosures are in course of development in this case—one parallel to the orthopinacoid, and the other parallel to the clino-pinacoid. Seen with a magnifying-power of 75 diameters. (See page 379.)

6. Structure of the pseudo-hypersthene from the olivine-gabbro of Loch Coruiskh, Isle of Skye. Represented as seen with a magnifying-power of 225 diameters. Two sets of enclosures are seen in section, lying in planes nearly at right angles to one another. A third much less perfect series of enclosures, with irregular outline, is exhibited lying probably parallel to the basal plane. (See page 380.)

7. Crystal of highly ferriferous enstatite (amblystegite) from the olivine-gabbro of Loch Coruiskh, Isle of Skye. The crystal exhibits only the first traces of Schillerization. It exhibits the very strong pleochroism and the rhombic extinction characteristic of the species to which it belongs. Cavities filled with solid enclosures are developed in great numbers along the lines of crack, and a few tabular enclosures are developed along one set of parallel planes, so that the mineral is seen to be passing into the bronzite-modification. The crystal is shown magnified 30 diameters. (See page 380.)

8. Crystal of altered ferriferous enstatite, enclosing both felspar and diallage, from the olivine-gabbro of Loch Coruiskh, Isle of Skye. The crystal is slightly serpentinized in places. This crystal exhibits the bronzite-modification over the greater part of the section, one very conspicuous series of enclosures, seen in section, being well developed in it; but here and there a second set of enclosures, also seen in section, and a third, viewed in plan, are also exhibited. The crystal therefore illustrates the transformation of the bronzite-modification of enstatite to the hypersthene-modification. Magnified 100 diameters. (See page 380.)

Fig. 9. Section of a crystal of typical hypersthene from Labrador, seen with a magnifying-power of 30 diameters. Three sets of tabular enclosures, which are of extraordinary dimensions, are seen in this section, two in section and one in plan. One set of enclosures, seen in section, is very persistent over the whole area; a second, nearly at right angles, is developed along certain bands, probably of strain; and the third, seen in plan, are also crowded along the same lines. The enclosures seen in plan have often one straight edge (due to the limits of the negative crystals in which they are developed); but on the other sides they are irregular in outline, owing to the secondary materials of which they are formed not entirely filling the negative crystal. The material of the crystal in which these enclosures lie has lost nearly every trace both of colour and of pleochroism. (See page 380.)

PLATE XII.

Fig. 1. Represents the surface of a crack traversing a crystal of olivine in the gabbro of Halival, Isle of Rum, as seen with a magnifying-power of 225 diameters. The irregular cavities sometimes contain a liquid and bubble, and at other times are empty; more usually, however, they are filled, to a greater or less extent, with dark-coloured, solid materials which appear to be decomposition-products. By the use of very high powers and special means of illumination fine reticulating tubules can be detected uniting many of these cavities. (See page 382.)

2. Shows the surface of a crack traversing an olivine crystal in the picrite of central Rum. In addition to cavities filled with decomposition-products, we find a beautiful dendritic network of magnetite and other oxides, spreading itself over the surface of the crack. The object is shown as it appears with a magnifying-power of 100 diameters. (See page 382.)

3. Portion of crystal of olivine from the picrite of central Rum, magnified 50 diameters. Showing enclosures along cracks filled with solid substances, as in fig. 1; dendritic ramifications of magnetite over the planes of cracks, as in fig. 2; and, in addition, numerous enclosures in negative crystals arranged in a series of parallel planes traversing the crystal. (See page 382.)

4. Very large and beautiful examples of the stellate bodies lying within the negative crystals in olivine, from the picrite of Halival, Isle of Rum. Magnified 75 diameters. In the crystals on the left, the stellate enclosures are viewed in plan and their forms are well seen; in the crystal on the right they are greatly foreshortened. When the plane of the section is at right angles to that of the plane parallel to which the negative crystals lie, the enclosures appear as fine dark lines. This section also shows the lines of cavities filled with solid substances passing along cracks in the olivine-crystals. (See page 382.)

5. A series of examples of very fine and large stellate enclosures in olivine from the picrite of Halival, Isle of Rum. Magnified 225 diameters. (See page 385.)

5*a*. Illustrates the first stage in the formation of the stellate enclosures in the negative crystals in olivine. The ramifying rods of magnetite &c. are assuming a radiate arrangement, but have not united with one another.

5*b*. Shows a very large and perfect stellate enclosure; the edges have not extended to the limits of the negative crystal, and therefore are not bounded by regular lines.

5*c*. Shows two stellate enclosures, the growth of which has been interfered with by the sides of the negative crystal. They also illustrate the tendency of the stellate enclosures to pass into tabular ones by additional deposits between the rays of the star.

5*d*. Illustrates the effects of foreshortening on the apparent forms of these stellate enclosures.

Fig. 6. Crystal of olivine, with magnetite developed along the cracks and invading the substance of the crystal. In addition stellate enclosures of magnetite &c. are making their appearance in negative crystals arranged in a series of parallel planes traversing the crystal. From the troctolite at the top of Halival, Isle of Rum. Crystal shown magnified 100 diameters. (See page 383.)

7. Portion of a crystal of olivine in which magnetite has been developed along the cracks to such an extent as to render black and opaque nearly the whole crystal. Portions of the olivine-substance, partially converted into serpentine, remain here and there in the midst of the mass. From the olivine-gabbro, Beinn More, Isle of Mull. Shown magnified 50 diameters. [In the same rock many of the olivine-crystals are seen rendered altogether black and opaque by the development of magnetite particles in them.] (See page 383.)

8. Crystal of biotite cut at right angles to the basal plane, and showing Schillerization along the planes coinciding with those of the principal cleavage; from the scyelite of Loch Scye, Caithness. Seen as magnified 50 diameters. (See pages 383 and 405.)

9. Two thin flakes of the same biotite, lying parallel to the plane of easy cleavage of the mineral, magnified 100 diameters. The enclosures are seen to be more or less regular plates, very similar to those found in the hypersthene of Labrador. Two grains of magnetite are also seen enclosed in the same crystal. (See pages 383 and 405.)

Plate XIII.

Varieties of the Ultra-basic Rocks of Scotland. All the sections are represented as seen with a magnifying-power of 30 diameters

Fig. 1. Olivine rock (dunite) of the Shiant Isles. Consisting of a mass of granules of clear olivine, only rarely showing faint signs of serpentinization. A few scattered particles of brown augite, of anorthite, and of magnetite (or chromite) are scattered among the olivine-grains which make up the bulk of the rock. The olivine is clear and almost entirely free from enclosures of secondary origin. In the form of the olivine-grains this rock resembles the dunite of St. Stephan in Upper Styria; but in the perfect freshness of the olivine it finds its analogue in the typical dunite of the Dun Mountain, near Nelson, New Zealand. (See page 394.)

2. Porphyritic olivine rock (dunite) from the flanks of the mountain of Scuir na Gilean in the Isle of Rum. The rock consists of an aggregate of minute olivine-grains with a little augite, through which larger crystals of olivine are scattered. These larger crystals exhibit the dusty appearance produced by the development of numerous stellate and tabular enclosures in negative crystals, and lying in two intersecting sets of planes within the crystal. The olivine is quite free from any trace of serpentinization. (See page 391.)

3. Olivine-augite-enstatite rock (lherzolite) from the top of Halival, in the Isle of Rum. The structure of this rock is intermediate between the *granitic* and the *ophitic*. The olivine forms rounded grains containing a few large stellate enclosures, and is often enclosed in the augite or enstatite; the augite is bright green in colour, and is not improbably a chrome-diopside, and the enstatite is a ferriferous one (proto-bronzite or proto-hypersthene), of a rich brown colour, with very marked pleochroism. Scattered through the rock are a few grains of chromite or picotite. Felspar is only present as a rare and accessory ingredient of the rock. The augite and the enstatite show slight traces of Schillerization. These two minerals cannot be distinguished in the drawing. (See page 392.)

4. Ophitic picrite (augite-olivine-rock) from the Shiant Isles. The rock is made up of very large crystals of deep brown augite, which enclose numerous rounded grains of olivine, while these latter, in turn, enclose rounded grains of chromite or picotite. The minerals of this

rock are free from all traces of Schillerization. The crystals of augite are so large that one fills up the whole field of view. (See page 394.)

Fig. 5. Anorthite-olivine-rock (troctolite) from the top of Halival, in the Isle of Rum. The rock, which constitutes a vein traversing olivine-gabbro, consists of a mass of interlacing anorthite-crystals, through which are scattered grains and aggregates of grains of olivine. The olivine is crowded with large stellate inclusions, and its outlines and cracks are rendered black and opaque. Except in the freshness of its minerals and in its finer grain, this rock exactly resembles the forellenstein of Volpersdorf and the Hartz. The scale on which the minerals are developed is, however, somewhat smaller. Sections of the Scotch rock would resemble that of Volpersdorf if the former were magnified three times more linear than the latter. (See page 395.)

6. Anorthite-augite-rock (eucrite) from Halival, in the Isle of Rum. This rock, which also forms veins in the olivine-gabbros, consists of a mass of interlacing anorthite-crystals, perfectly unaltered, through which are distributed granular particles of an augite of a green colour, which is more or less perfectly converted into diallage by Schillerization. In some parts of the rock, a ferriferous enstatite is added to the two principal constituents, and this mineral sometimes prevails almost to the exclusion of the augite. This eucrite is of a decidedly granulitic structure, but other rocks of the same mineralogical constitution are coarse-grained and distinctly granitic in structure. (See page 395.)

7. Altered, ferriferous-enstatite-rock (bastite-rock) from Carrock Den, Forfarshire. This rock occurs in the midst of a great dyke of serpentine which traverses the Old-Red-Sandstone strata; it is made up of an aggregate of ferriferous-enstatite-crystals in a somewhat altered condition, the whole being traversed by cracks filled with serpentinous material. Except for the amount of alteration the rock has undergone, it exactly resembles the "bronzite-rock" of Kupferberg in Bavaria, and of St. Stephan in Upper Styria. (See page 399.)

8. Mica-hornblende-picrite (scyelite) from an intrusive mass near Loch Scye, in Caithness. A number of grains of olivine, now converted into serpentine, are enclosed in crystals of pale green hornblende (seen in the lower left-hand part of the slide), paramorphic after augite, and of a highly magnesian biotite (seen in the upper right-hand part of the slide). The biotite is, in places, darkened by numerous inclusions arranged parallel to the basal plane, or in the direction of the principal cleavage. (See pages 401–407.)

Figs. 1–6 are from Tertiary rocks.
Figs. 7 & 8 are from Palæozoic rocks.

Discussion.

Mr. Rutley said that the points raised in the paper were so numerous that it became very difficult to discuss. The twin-structure in calc-spar was probably produced by pressure; but with regard to triclinic felspar the case seemed different; and he felt doubtful whether all twinning could be developed by pressure; for, if so, the same structure would be produced in orthoclase. Besides, twinning usually occurred in two directions in the triclinic felspars—namely, parallel to the basal plane and to the brachypinakoid. If due simply to pressure, why should it not sometimes occur parallel to the macropinakoid? The proposed term

Schillerization might prove useful, but he questioned whether some of the results attributed to it might not be due to weathering.

Mr. Bauerman felt the same difficulty that had been alluded to by the previous speaker in entering upon the discussion of this paper. He remarked that the twinning of triclinic felspars was not an essential peculiarity, as he had seen specimens in which it was absent; but he considered the origination of twinning from pressure unproved, as there was no difference of cohesion in different directions sufficient to produce twinning. Twinning is especially well seen in albite crystallized freely in druses in mineral veins. Pseudostructures of lower symmetry in boracite &c. are due to change of structure produced in cooling, and quite distinct from twinning in felspars.

Rev. E. Hill said that all banding that he had observed in igneous rocks, glass, &c. varied gradually from point to point when due to pressure, and thus differed from that described by the Author.

Mr. Hudleston remarked that magnesian rocks were very mysterious. Their peculiarities are perhaps due to chemical composition. Gabbros are always found associated with serpentine and olivine rocks. He inquired whether Schillerization might not be due partly to change of structure arising from something inherent. As a case of change resulting from original peculiarity of composition, he quoted the analysis of a rock lately described by Mr. Teall, which showed an amount of magnesia unusual for a non-olivine dolerite. There was no mineral in that rock to absorb so much magnesia except the augite, which must have possessed an exceptional composition, and consequently an inherent tendency to change: such inherent tendency might help to explain the phenomena of Schillerization. He further commented on the alterations stated to have taken place in depth; for some Schillerized rocks, *e.g.* bastite, are hydrated forms.

Prof. Hughes asked how far the relations of the rocks in question to one another and the conditions of depth &c. could be considered well established. In the example exhibited he thought the vein called gabbro was due to alteration along a joint, of which he saw traces on the back of the specimen in the divisional plane which ran almost through the middle of the vein. It looked like a vein along a faulted joint, and might be of any age later than the olivine rock and subsequent to the jointing and faulting, and therefore not belonging to deep-seated conditions.

The President congratulated the Author on having, as he said, driven another nail into the coffin of the classification of igneous rocks by their geological age. He had always believed that the altered peridotites of the Apennines were of Tertiary age. In all cases that he had seen, the gabbro and peridotite were quite independent rocks; but he had seen picrite pass into diorite. He himself had always found gabbro the newer rock, evidently deep-seated; for the crystallization was coarse even in small veins. He also doubted whether plagioclastic twinning was due to pressure; for it is found in rocks not much pressed, such as lava-streams.

He thought the mystery about magnesian rocks was artificial. He suggested that the presence of diallage in deep-seated rocks might be due to hydration owing to depth, because the water could not escape. Amphibolization is well illustrated in the gabbro of Cornwall, when diallage is converted into hornblende at the surface.

The Author, in reply, said he did not mean to assert that mechanical strain produced twinning, but only develops it where the tendency already exists. It has been shown that this structure is induced by pressure in calcite, and, if so, the same change is possible in the plagioclase felspars. The case is similar with leucite and boracite, in which, however, the twinning disappears on the mineral returning to the original temperature of its formation. The result of twinning in orthoclase is seen in microcline, and Lehmann refers microcline-structure in Saxony to pressure. Hypersthene was always, until lately, studied only in altered forms. Schillerized forms are produced by deep-seated hydration, weathered forms by hydration near the surface. In reference to the alleged association of diallage and magnesian minerals, he stated that several varieties of augite pass into diallage. In answer to Prof. Hughes he said that the veins in the specimens referred to are irregular injection-veins.

31. *On the* Structure *of the* Ambulacra *of some* Fossil Genera *and* Species *of* Regular Echinoidea. By Prof. P. Martin Duncan, M.B. Lond., F.R.S., F.G.S. (Read April 29, 1885.)

Contents.

I. Introductory Remarks.

The characters of the ambulacra of the Echinoidea have always been considered of primary importance in the classification of that great division of the Echinodermata.

The details of the structures of the ambulacra of the regular Echinoidea have been long known in the instance of the Cidaridæ, in some of the Salenidæ and Echinometridæ, and in many genera of Echinidæ.

The study of the structures led to the separation of the groups of genera with simple plates and one pair of pores to a plate from those having compound plates with three or more pairs of pores. *Cidaris* has been acknowledged as the type of the first group, and, thanks to the elaborate investigations of Lovén *, *Strongylocentrotus* may be considered the type of the other series.

In a monograph on the fossil Echinoidea of Sind, by the author and Mr. W. Percy Sladen, F.G.S., there is a description of two species of *Cœlopleurus* from the Oligocene, and the illustrations which accompany the work fully explain that there is a type of ambulacral plate which departs from the received idea regarding the intimate structure of plates with triple pairs of pores †. Subsequently some researches by the same authors proved that the Arbaciadæ and the recent Diadematidæ had their ambulacra constructed on a plan hitherto unobserved, and which separated the groups distinctly ‡. Having obtained a knowledge of the characters of the recent forms, the study of the corresponding details of the fossil species became tolerably easy.

The results of this study are now offered to the Society.

I have to thank the executors of the late Dr. T. Wright, F.R.S., for permitting me to examine and draw what was necessary from the beautiful specimens in their charge. I am also very glad to have the opportunity of thanking the authorities at the British Museum and at the Museum in Jermyn Street for allowing me to study the collections.

In the majority of fossil regular Echinoidea the pairs of pores of

* Lovén, Études sur les Échinoïdées, 1874, p. 19.
† 'Palæontologia Indica,' ser. xiv. fasc. iv. pl. xxxix. (1884).
‡ Journ. Linn. Soc., Zool. vol. xix. pp. 25 and 95 (1885).

the ambulacra can be readily observed; but the separations of, or the sutures which unite, the edges of the plates are usually not to be seen. Many weathered specimens of Oolitic and Cretaceous species show all the details of the ambulacra; and when they are imperfect or slightly confused, the knowledge of the position of the plates in the modern allies of the fossil forms renders the action of reagents almost invariably successful in distinguishing them. But it is not possible to make out the limits of the ambulacral plates in some specimens, and usually these forms are the most perfect in their state of preservation. Weathering and the action of Lovén's reagent, alcohol mixed with glycerine, assist the investigation of the fossils, and most liquids which permeate the plates and evaporate rapidly will assist in the investigation of recent Echinoidea.

II. General Remarks on the Structure of Ambulacra.

An ambulacrum extends from the actinal edge of a radial (ocular) plate to the edge of the peristome; it is composed of a number of plates which are placed in two rows or zones on either side of a vertical or median line, and each row consists of plates located in succession from the radial plate to the peristome. The plates of one row are united by suture with those of the other, and the junction occurs along the median line, the extremities of the plates being more or less angular. The plates of one zone are not on an exact level with those of the other, for the angle of one plate fits into the reentering angle which exists between two of the opposed plates. The edge of each plate in contact with the interradium is also more or less geometrical, but it may be rounded off in shape, instead of angular. The plates in each row are united actinally and abactinally with other plates. These unions are by suture.

Each plate has a poriferous zone, and the rest forms part of an interporiferous area; and there is a pair of pores to a plate. In well-preserved specimens the pair of pores is encircled by a raised dish-like structure called a peripodium, and the pores are never placed quite transversely or horizontally, but more or less obliquely, so that the pore nearest the median line of the ambulacrum is on a lower level than the other; that is to say, the inner pore is adoral to the other and is called the adoral pore. This pore is in contact, in the young Echinoid, with the line of division between two consecutive plates, and notches the edge of the peripodium; but it may become distant from the suture during growth. In the Cidaridæ all the plates are primaries, and each has its pair of pores. A primary plate is one which reaches from the poriferous zone to the median line or vertical suture, and which comes in contact there with others of the opposite zone. In the Cidaridæ the plates increase in number by developing just at the actinal edge of the radial plate, and one plate is formed after another.

At the peristomial end of the ambulacrum there is a corresponding

separation of successive plates, so as to produce the characteristic plating around the mouth seen in recent forms of *Cidaris*.

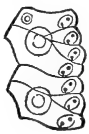
In the other families of the regular Echinoidea the addition of new plates also occurs at the edge of the radial plate; but there is a crowding of the plates more or less at the peristome, and the oldest plates there gradually become absorbed at the very edge. So that with the growth of the whole test in height there is a superabundant growth of the ambulacral plates, and, as Lovén has well shown, there is a downward or actinal movement of the ambulacral plates from the radial plate to the peristome. This movement is complicated by the fact that the ambulacral plates are all growing with the rest of the test, and enlarging in all directions at the surface. Moreover the growth-rate of some plates is greater than that of others, and those which carry tubercles appear to have a greater growth superficially than others. Consequently irregular pressure is exerted by these plates on their neighbours, and the result is very remarkable. Again, the movement of the plates above the ambitus of the test, although comparatively free, is of necessity diminished near the peristome, in consequence of the more or less rigid state of the peristomial region incident to the position of the auricles of the jaws and their processes.

It is to these different facilities for and oppositions to a regular and symmetrical growth that the varied shapes and characters of the ambulacra and their plates are due.

It is an interesting and highly suggestive truth that all the regular Echinoidea should have their most radially situated plates in the form of the simple primaries of the Cidaridæ; but at different distances from the radial plate modifications begin to be seen, and they are characteristic and of generic and specific value.

The modifications which were known and which had been carefully described by Lovén before the publication of the "Fossil Echinoidea of Sind," in the 'Palæontologia Indica,' ser. xiv., were those which characterize the Echinidæ and some other forms, such as *Strongylocentrotus* (fig. 1). In these the growth-pressure develops com-

Fig. 1*.



pound plates by jamming and uniting the original primaries; moreover the part of the primary remote from the poriferous portion is often prevented from growing, or is absorbed by the growth-pressure. The result is the formation of demi-plates which do not reach the median line. Moreover the downward growth and the other varieties of growth-expansion cause combinations of several plates, and produce compound geometrical forms made up of three, four, five, and even

* For the explanation of this and the following figures, see pp. 451, 452.

more plates, all more or less departing from their original shape. Growth near the unyielding peristome produces shifting of the poriferous parts of plates, and hence the apparent confusion of the pairs of pores in that region in so many genera. It must be understood that the confusion is only apparent, for Lovén has explained it, and no additional pairs of pores intercalated there during growth.

The physiological importance of the ambulacra to the Echinoid cannot be over-estimated; for the peripodia support the prehensile or motor tentacles, and in the Arbaciadæ and the Diadematidæ the tentacles which are above the ambitus have a non-prehensile and branchial function. The number of tentacles placed within a given area is therefore of classificatory as well as of physiological importance, and this number bears a definite relation to the number, kind, and shape of the plates which constitute the ambulacra.

The Echinoidea with the simplest ambulacra are found in the lower Secondary deposits, and it is advisable in the present inquiry to commence with the description of some of the earlier forms of the Diadematidæ. It is proposed to consider the genera *Hemipedina*, Wright, *Pseudodiadema*, Desor, *Pedina*, Agass., *Stomechinus*, Desor, *Hemicidaris*, Agass., *Diplopodia*, McCoy, and *Cyphosoma*, Agass.

III. Descriptions of the Ambulacral Plates of the Genera Hemipedina, Pseudodiadema, Pedina, Stomechinus, Hemicidaris, Diplopodia, and Cyphosoma. The Necessity for a new Genus, Plesiodiadema.

Genus Hemipedina, Wright, 1855.

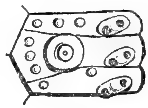
The diagnosis of this genus will be found in the 'Monograph of the British Fossil Echinodermata,' Pal. Soc. Lond. 1855, p. 143.

Dr. Wright made the following remarks concerning the affinities of this genus with other genera:—"*Hemipedina* is related to *Pseudodiadema* in having the pores unigeminal and the tubercles perforated; but it is distinguished from *Pseudodiadema* by the absence of crenulations from the summit of the bosses. It is related to *Pedina* in possessing perforate and uncrenulate tubercles; but it is distinguished from that genus in having the pores unigeminal, *Pedina* having the pores trigeminal as in *Echinus*. The elements of the disk are likewise more largely developed. *Hemipedina* is related to *Echinopsis*, but is distinguished by the narrowness of the ambulacral areas, the general depressed form of the test, the shape of the mouth-opening, and the deep decagonal lobes of the peristome (that of *Echinopsis* being almost deprived of incisions), together with the greater size and development of the elements of the apical disk." In the drawings of a species of *Hemipedina*, Dr. Wright noticed the long slender needle-shaped spines with fine longitudinal striations. He states, moreover, that the optic pore is in the centre of the radial plate.

Hemipedina Jardinii, Wright, has a considerable series of low and

broad primaries near the radial plate, and extending far towards the ambitus, and each plate is united by a separable suture to the plates situated apically and actinally. At the ambitus three primaries are seen to form a compound plate geometrical in figure, and their separability is at an end. There are triple plates of this character down to the peristome. Taking a compound plate at the ambitus (fig. 2) as the example, it appears that it is

Fig. 2 (see p. 451).



broader than high, and that the pairs of pores, three in number, are either straight or in a very slight curve. Two lines of suture cross the compound plate, and they indicate the edges of the primaries which have united to form it. One line is between the aborally situate plate and the middle one of the combination, and it passes from the adoral pore of the aboral pair inwards to cross the base of the tubercle apically to the mamelon, and thence it passes on to the median suture of the compound plate or, as it is called, the vertical suture or edge. This line is very faintly curved with the convexity towards the tubercle, or it may be straight and cross the flank of the boss. The other sutural line is between the middle plate and the adoral plate, and it is in contact with the adoral pore of the second or middle pair; thence it crosses the adoral flank of the boss actinally to the mamelon and reaches the vertical suture with or without a curve. The aboral plate of the combination is a low and broad primary which includes a small portion of the boss, and the adoral plate is of the same configuration as the other. The middle plate is rather the largest, and is a well-formed primary which carries much of the boss of the tubercle and all the mamelon.

The sutural lines between the plates constituting the compound plates are in some instances decidedly curved, with the convexity placed towards the mamelon; but this condition is replaced nearer the peristome by quite straight lines. The formation of the almost rectangular primaries in the combination resembles a simple apposition of *Cidaris*-like plates, and it is interesting to notice this primitive type merging gradually into the fully developed one, in which, as in the ancient and modern Diadematoids, the curving of the sutural lines is coincident with an enlargement of the middle plate towards the median line at the expense of the plates above and below, these plates then departing from the shape of those of the Cidaridæ.

Hemipedina Bowerbankii, Wright.

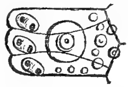
There are some fine examples of this species in the Museum of the

Geological Survey, Jermyn Street, and in most the number of single primary plates near the apical end is very striking, indeed almost leading to the idea that all the parts of the ambulacrum are made up of them. But there are one or two compound plates preserved. In one of these, near the peristome, the triple nature is evident, and the line of suture between the middle and adoral plates is curved, and passes from the adoral pore of the middle pair towards the mamelon of the tubercle and thence to the median or vertical suture, the convexity of the curve being directed apically. In another specimen the line of suture between the middle and the aboral plate is seen, and it is curved, with the convexity towards the mamelon. Hence these compound plates are on the Diadematoid type, and it may be presumed from the phenomena presented by the recent species of *Diadema* that growth-pressure has changed the shape of the original primaries. In one of the specimens in the Museum there are four plates and four pairs of pores in one of the compound plates, and it appears, but not very satisfactorily, that the additional plate is a low primary. This is not without its significance; for a similar structure is seen in allied genera *.

Hemipedina marchamensis, Wright, from the Coral Rag, is a fine form belonging to a section of the genus which has numerons primary tubercles in rows on the interradia.

There is a specimen in the British Museum (no. 75923) which shows the shape of the triplet of plates which combine to form a geometrical plate near the ambitus. The compound plate is broader than high, and there is a space between the tubercle and the median or vertical suture (fig. 3). The direction of the sutures between the

Fig. 3 (see p. 451).



three plates indicates their shape, especially as the whole compound plate is contained between an aboral and an adoral transverse suture.

The pores are rather oblique, and the adoral pore of the first pair is on the suture which unites the first and middle plates. The line of this suture is, from the interradium to the adoral pore, and thence with a curve, convex adorally, up the flank and over the top of the boss of the tubercle apically to the groove at the base of the mamelon, and then down the slope to the edge of the boss to reach the median suture at a short distance from the aboral and inner angle of the compound plate.

This first plate is therefore a low primary resembling the corre-

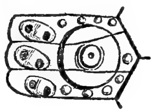
* With regard to *Hemipedina Bowerbankii*, Wright (*op. cit.* p. 145), illustrated on plate ix. of the Monograph already noticed, it must be observed that the figure 2 *b* cannot be correct. It represents the pores as if they were turned upside down, and the adoral pore, or that which is furthest from the interradium, as aboral to the other in position.

sponding plate of a modern *Diadema*. The middle plate is lowest at the centre of the tubercular area, for it is nipped in by the curved edge of the first plate and also by an aboral curvature of the third plate. But further towards the median line the middle plate, after carrying the mamelon, expands, and is in relation with much of the boss and the greater part of the compound plate. The third plate has its aboral edge curved apically, and it is a low primary, for the suture between it and the middle plate reaches the median suture just abactinally to the adoral and inner angle of the compound plate.

The resemblance of these plates to those of the typical and recent *Diademata* is exact.

Perhaps the most striking species of *Hemipedina* is *H. tuberculosa*, Wright (*op. cit.* p. 164), on account of its resemblance to a *Hemicidaris* without crenulation, and with an unusual number of small secondary tubercles in the interradia. It is a beautiful form, and is even more *Cidaris*-looking than *Hemicidaris*. The ambulacral plates, however, do not always remain as simple primaries; for towards the ambitus, where the tubercles increase in size rather suddenly, there are three pairs of pores evidently in relation to as many plates which have combined to produce a geometrically shaped compound plate (fig. 4). The triple pairs may arch very slightly

Fig. 4 (see p. 451).



around or be straight at the edge of a great tubercle, which nearly covers the entire plate. The peripodia, which are only slightly oblique and broadly elliptical in shape, are not so crowded as they are in *Hemicidaris*; but they impinge upon the outer flank of the tubercle, and in some specimens their relation to the plates which their pores perforate can be appreciated.

Taking the first tubercle above the ambitus, it will be noticed to be situated apically to a decidedly large one, and to be separated from it by more space than exists between the other tubercles placed in succession towards the peristome. The three peripodia are in a slight arc, and the most adoral is slightly nearer the tubercle than the others. The tubercle is a broad, low cone, with a well-developed mamelon surrounded by a decided groove. Careful observation proves that the adoral pair of pores has the adoral pore on a line with a transverse suture which separates the combination to which this poriferous plate belongs from the next plate in actinal succession. And on the adoral flank of the tubercle, and nearer the base than the groove around the mamelon, is a line which can be traced from the adoral pore of the peripodium which is the middle one of the triplet, over the slope of the boss to the median line of the ambulacrum.

The line is that of the suture between the lower and middle plates of the compound plate, and it limits the lower plate aborally and the middle plate adorally. As this suture reaches the median line, and as the transverse suture below also does this, the lower or adoral plate of the triplet is a more or less rectangular primary.

On looking at the apical and inner part of the tubercle a line may be seen passing along the side of the base of the tubercle and going obliquely upwards, or aborally, to the vertical or median suture. This line is to be traced over the boss aborally to the mamelon to the adoral pore of the first pair of the triplet.

It is the suture which separates the aboral (or first) and the middle plates of the triplet; and as it reaches the median line, the plate above it, or the first of the series, is a primary, highest at the poriferous zone and low at the median line. This first plate is bounded aborally by the transverse suture which adorally limits the plate placed immediately abactinally, and which does not form part of the compound tubercle-bearing plate under consideration. The shape of the middle plate of the combination is determined by the direction of the suture of the edge (adoral) of the first plate and of that (aboral) of the third plate. The plate expands in the direction of the median line aborally, and, moreover, is covered by the mamelon and by much of the boss.

The structure of the tubercle-bearing compound plate immediately adoral to the last is very simple. The tubercle nearly covers the whole plate, except the narrow poriferous zone, and the peripodia are rather oblique and in an arc, so that the third is nearer the median line than the first of the triplet.

The course of the sutures from the adoral pores of the peripodia is the same as in the simpler forms of *Pseudodiadema* and of the modern *Diademata*. All the plates of the compound one are primaries, and the middle one is the largest: it is covered by the mamelon and by most of the tubercle near the median line, as well as by that portion of the boss which lies on a transverse line with the second peripodium. The suture at the adoral edge of the first plate crosses the boss to the vertical suture with a slight convexity directed actinally, and the suture at the aboral edge of the third plate crosses the boss in the same manner, but the convexity is directed apically. Hence the middle plate is expanded towards the median line, low at the part where the mamelon is, as it were, nipped in between the first and second plates, and not so low at the poriferous part. The first plate is lowest in vertical measurement at the vertical suture, and so is the third plate. The transverse suture which bounds the compound plate adorally is in contact with the adoral pore of the third pair.

There are no demi-plates in this species, and the compound plates are different in construction from those of *Hemicidaris*.

Genus PSEUDODIADEMA, Desor.

Desor ('Synopsis,' p. 63) gives a short diagnosis of this genus, and classifies it in his group of Oligopores, that is to say in a division of

the regular Echinoidea, the forms of which have three pairs of pores only to each ambulacral plate.

Test of moderate or small size. The tubercles are of the same size in both areas, and are crenulate and perforate. The tubercles either only form two rows in the interradia, and may be without secondaries, or they may be arranged in four or even six rows.

Poriferous zones simple. Spines smooth or faintly striated.

Range from the Lias to the Cretaceous inclusive.

Desor notices that the forms thus diagnosed were termed, in the 'Catalogue Raisonné,' "*Diadema*," and were placed alongside of the recent species which bear that generic appellation. But besides being smaller than the modern forms, there is the character of the latter which relates to the spines to be considered, according to Desor. He reminds us that the spines in the modern species of the genus *Diadema* are verticillate in their striated ornamentation.

Under the belief that this distinction was of great classificatory importance, he separated the species which are found fossil, as belonging to the genus *Pseudodiadema*, and took two species as typical of two divisions of the genus—*Pseudodiadema hemisphæricum* (*Cidarites pseudodiadema* of Lamarck, or *Diadema pseudodiadema*, Agass. & Desor) and *Pseudodiadema mamillanum*, Römer. The first he considered represented the group with several rows of secondary tubercles in the interradia; and with the latter he associated all the forms with only two rows of tubercles in an area.

It will be noticed that in the diagnosis Desor did not find a place for certain species which have been admitted since, and which have a doubling of the pairs of pores in the region above the ambitus. McCoy had separated the species with doubling of the pairs near the apex from *Diadema*, and had founded the genus *Diplopodia* for them. Wright, however (*op. cit.* p. 109), adds to the generic characters of *Pseudodiadema*, "the pores in one section are unigeminal throughout, and in another section they are bigeminal in the upper part of the zones."

The same author states that *Pseudodiadema* differs from *Diadema* in having solid spines, with a smooth surface, the sculpture, in most cases, consisting of microscopic longitudinal lines. He also remarks that the genus differs from *Cyphosoma* in having the tubercles always perforated. The necessity for allying *Cyphosoma* and thus adding to the confusion is a consequence of admitting forms with doubling of the pores into the genus *Pseudodiadema*. Wright noticed the genus *Diplopodia*, and remarks as follows in placing it on one side:—"*Cœteris paribus*, the crowding together of a greater number of pores in a zone is, at most, a sectional, and can never form a stable generic character, inasmuch as it is subject to great variation in the diplopodous species themselves, and is, moreover, often only an adult development."

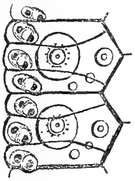
Having studied the morphology of the ambulacra of the recent Diadematidæ (Journ. Linnean Soc., Zool. vol. xix. p. 95) I was greatly impressed with the results of a careful examination of many forms of the allied genus *Pseudodiadema*. I came to the conclusion

that the whole subject of the classification ought to be reinvestigated, the morphology of the ambulacra being considered of primary importance. It became easy, after the examination of weathered specimens, to decide that whilst some recognized species of *Pseudodiadema* were evidently Oligopores and closely allied to the modern *Diadema*, others were Polypores, having sometimes as many as five or six pairs of pores to an ambulacral plate. Again, some species are allied to the recent forms by having the optic pores at the actinal margin of the radial plate, and by having decided branchial cuts and even tags arising from the cuts. Moreover the structure of *Cyphosoma* being known to me, I could hardly consent to so close an alliance as Dr. Wright suggested between it and *Pseudodiadema*.

Pseudodiadema hemisphæricum is well drawn by Bone in Dr. Wright's Monograph of the Brit. Foss. Echinodermata, pt. 1, 1855, plate viii. The shape of the radial plates and the position of the optic pore at the very margin of the plate are clearly indicated, and the drawing of an ambulacrum (fig. 1 *d*) shows the relation of three pairs of pores to each tubercle-bearing plate. The exact relation of the pairs is not shown; for the specimen was so perfect that no sutures probably were visible. But in the British Museum there is a specimen (No. 23329) from Malton, named, as of old, *Diadema pseudodiadema*, and the lines of the sutures may be seen here and there.

In the great majority of the ambulacral plates there are three pairs of pores. Each pair is in a primary plate, and the three primaries have become fused, as it were, into a geometrical compound plate (fig. 5).

Fig. 5 (see p. 451).



The first or aboral pair of pores of this compound plate has its adoral pore in contact with the adoral suture of the low broad primary plate which forms the first or apical portion of the compound plate; and this suture is directed to the median or vertical suture in a course which is somewhat curved, the convexity being adoral.

The suture crosses the boss of the tubercle just abactinally to the mamelon.

The pair of pores which belongs to the middle plate of the combination has its adoral pore in contact with a suture that unites its adoral edge with the aboral edge of the third plate. The direction of this suture is towards the median suture, and it has a path from the interradial end of the poriferous zone to the adoral pore just noticed, and thence with a curve directed apically,

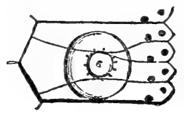
reaching the boss adorally to the mamelon. The course is then to the median suture, and the termination is close above the adoral and inner angle of the compound plate. The middle plate is low at the poriferous zone, nipped in vertically at the boss, where it includes the mamelon, and expanded towards the median line.

The adoral plate of this combination has an arched aboral edge and is a low and broad primary, smaller in vertical measurement at the median line than at the poriferous part.

The pairs of pores are in peripodia, and the amount of arching is slight. This description would suffice for a compound plate near the ambitus of a recent *Diadema*.

But the fossil form has some compound tubercle-bearing plates at or just below the ambitus, which are polyporous; for there are distinctly four pairs to a compound plate, and not three only (fig. 6).

Fig. 6 (see p. 452).



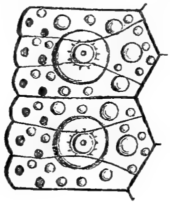
There are therefore four plates in the combination, and all are not primaries, there being a small demi-plate (*b*) amongst them which does not reach the median line. The aboral or first plate (*a*) of the set resembles the corresponding plates of the combination already described, and is a low and broad primary with the adoral edge bent actinally. The second plate (*b*) is a demi, and it reaches a little way up the tubercle, and is bounded aborally by the edge of the first plate, and adorally by part of the suture of the third plate in its path to reach the median line. Part of the third plate (*a'*) has the shape of the middle plates of the combinations in which there are only three pairs of pores, but it is rather lower, and the fourth plate (*a''*) resembles the adoral plates of the triple compound plates. The second plate is the relic of a primary which has undergone absorption owing to that growth-pressure which is so easily traced in some recent forms of Diadematidæ. The recent species of *Diadema* do not, however, present this phenomenon, and there are no demi-plates in them.

The simplest form of fossil Diadematid is a species which, had it doubling of the pairs of pores close to the peristome, would fall within the specific diagnosis of *Pseudodiadema depressum*, Agass.

The specimen in my possession was obtained by Prof. J. Morris, M.A., from the Cornbrash of the Chippenham district. It has nearly straight rows of pairs of pores, the outer pores being larger than the inner. There is but slight obliquity of the pores, and the pairs are not close. There are three pairs to each tubercle-bearing compound plate, and the three plates are primaries of the true *Diadema* type (fig. 7). The commencement of the compound plates is very close to the radial plate, and there are only one or two solitary

uncoalesced primaries. Near the peristome the simplicity of the compound plate persists, and there is no crowding of the pores. An

Fig. 7 (see p. 452).



interesting structure exists in the form of a tag, which, as in the recent *Diademata*, passes up from the branchial cut by the side of the ambulacra. So far as the test is concerned, or rather that part which remains, the apical system being deficient, there is no distinction to be made between this species and a recent *Diadema*.

There are many species included in the genus *Pseudodiadema* by authors which have the simple triplet arrangement of pores just noticed, and the peristomial crowding never amounts to a displacement of pairs or the production of demi-plates. I have been able to examine many of the forms described by Dr. Wright, thanks to the courtesy of his executors. The type of this group existed from the Inferior Oolite, if not from the Lias, to the Cretaceous age inclusive; and it is a matter of great interest to have been told that hollow, striated, and verticillate spines were found in the Chalk and drawn by Mr. Bone. The *Pseudodiademata* with simple triplets form, therefore, one distinct type or group. The *Pseudodiademata*, having also occasionally an additional pair of pores belonging to a demi-plate, belong to a closely allied section or subgenus or group.

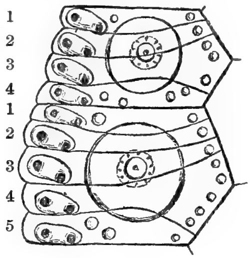
The next type to be considered, the third group, is one in which there are never less than four plates and four pairs of pores to a compound plate, and of which *Pseudodiadema mamillanum* already alluded to, is an example.

In most of the specimens of this series there is barely any trace of the divisional sutures to be seen in those plates which have the greatest number of pores; but an instance of a form clearly presenting all the necessary structures to view from which a drawing can be made is in Dr. Wright's collection*. Having examined the specimen, it is evident that a compound plate at the ambitus has no less than five primary plates entering into its composition, and that the next above or aboral compound plate has four (fig. 8). The pairs of pores are in slight arcs, the peripodia are well developed and often occupy nearly or quite the whole height of the poriferous area of the plate on which they are placed. The adoral pore of a pair is always in relation with the suture between its plate and that

* *Pseudodiadema Michelini*, Agass.

which is placed immediately actinally. The tubercle of the compound plate is large, and there is some space between it and the median suture.

Fig. 8 (see p. 452).



Taking the compound plate above the ambitus, first of all, for descriptive purposes, there are to be noted four plates and four pairs of pores in peripodia. The actinal or fourth plate (no. 4) is a low and broad primary having a convexity directed aborally, so that the plate is low in the poriferous zone and at the median line of the ambulacrum, and much higher midway where it reaches across the adoral part of the base of the boss. The next plate situated abactinally (no. 3) is the largest of all in the compound plate, and assimilates in shape to the middle plate in the triplet of a *Diadema*; it is largest near the median suture of the ambulacrum, is nipped in on the tubercle, and is somewhat higher at the poriferous zone. The adoral pore of its pair is in relation with the suture between its adoral edge and the aboral edge of the plate just described. The abactinal edge of the plate now under description crosses the boss and the centre of the mamelon, and then passes towards the median line, with an abactinal and inward path, so as to give a curved appearance to the suture which joins this plate to the one immediately above. The third plate from the adoral edge, or no. 2 of the compound one, is a long or rather broad, low primary, the actinal edge of which corresponds with the abactinal curved edge of the plate just described. So this third plate has a bent actinal edge, and this is indicated by the suture. The abactinal edge of the plate is also curved, and with the convexity directed actinally, and the height of the plate at the median line of the ambulacrum is small and less than at the poriferous zone.

The most apically placed of the plates, or the first (no. 1), is a low and broad primary, lowest at the vertical suture, and with the adoral edge curved adorally, the abactinal edge being straight and transverse. The adoral edge of this plate crosses the tubercle not very far from the mamelon. The transverse aboral edge is in contact with the actinal plate of the compound plate situated immediately abactinally.

All four plates combine to form a solid compound plate, and they are to be recognized by the direction of their sutures. The angle

of the compound plate at the median line is formed by the large primary (no. 3).

It will be observed that this arrangement of the component plates is not like that of the species already noticed, in which an occasional fourth plate has been sometimes produced; for in the present instance there is no demi-plate to be seen, and all the plates are primaries.

The compound plate at the ambitus (fig. 8) has a larger tubercle than the one immediately above, and is larger altogether. It has five plates entering into its composition, and there are therefore five pairs of pores and five peripodia; these are in an arc, and the third pair from the abactinal edge of the compound plate is the most remote from the median line of the ambulacrum.

The first, second, and third plates from the abactinal edge are formed after the model of the abactinal plates 1 and 2 of the compound plate above, and they are low and broad primaries with a curved adoral edge. The fourth plate is the largest, and corresponds in shape to the third plate from the abactinal edge of the compound plate above; it is on the type of the middle plate of a *Diadema*, and is expanded towards the median line, and is lower on the tubercle, the actinal half of which, and sometimes more, it carries.

The last and actinal plate of the combination (no. 5) is a primary, low at the median suture, slightly higher at the poriferous zone, and with an arched aboral edge which curves towards the mamelon and just reaches the tubercle. The adoral edge of the plate is transverse and straight, and it is the actinal boundary of the compound plate.

Thus the three actinal plates of this compound plate resemble in shape and in position the three adoral plates of the compound plate above, and it appears that the additional plate of the ambital compound is either the fourth or fifth from the actinal edge. Great as the downward growth-pressure must have been, there are no demi-plates. I have not had access to some of the most important polyporous species figured in Dr. Wright's monograph, but which do not belong to his collection, and I can therefore only assert that in all the forms of the group which have been examined by me there is an absence of the demi-plate.

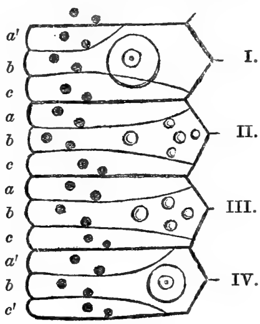
Considering the first two groups of forms hitherto named *Pseudodiadema*, it is evident that the ambulacral structures unite them, and at the same time separate them from the polyporous group. It is interesting to note that these simple forms are the oldest; they differ from the recent species of *Diadema* in shape and size at maturity, and in the comparative height of their plates. Moreover the occasional demi-plate in the tubercle-bearing plate constitutes a distinction; for this is not seen in the modern forms. The details of the peripodia of the ancient and modern forms are not quite the same.

With regard to the spines there is much difficulty in making very definite distinctions, and there are many loose spines found in the Secondary series of rocks which are comparable with those of *Diadema*.

It appears consistent with the results of these researches to decide that the genus *Pseudodiadema* should be restricted to the forms with triple plates, with an occasional extra plate in the nature of a demi-plate; that is, to groups one and two. Of such a genus the species placed in the following list may be taken as common forms:—*Pseudodiadema Moorei*, Wright; *P. depressum*, Ag.; *P. radiatum*, Wright; *P. Bakeriæ*, Woodw.; *P. priscum*, Cott.; *P. inæquale*, Des.; *P. Wrightii*, Cott.; *P. prisciniacense*, Cott.; *P. rotulare*, Ag.; *P. Benettiæ*, Forbes; *P. ornatum*, Goldf.; and the species which has been partly described in this communication. *Pseudodiadema Brongniarti*, Ag., and *P. Bailyi*, Wright, may be taken as good examples of the subgroup with an occasional demi-plate; and of course *P. hemisphæricum* is the type.

On the other hand, the species with at least four and with five pairs of pores or more, both in forms not full-grown and adult, should be ranged in another genus—*Plesiodiadema*. Under this genus will be arranged the species *P. mamillanum*, Römer; *P. Michelini*, Ag.; *P. Blancheti*, Des.; *P. Verneuilii*, Cott.; *P. tenuis*, Des.; *P. annulare*, Desor, &c.

Fig. 9 (see p. 452).



Genus Pedina, Agass.

The diagnosis of *Pedina* (an Oolitic genus) has been partly noticed (page 422), and it is now necessary to determine what distinction the obliquity of the triple pairs of pores makes in the shape of the plates.

Taking *Pedina Smithii*, Wright, as the type, an examination of the specimen in the late Dr. Wright's collection indicates that the ambulacra are different from those of *Hemipedina*. The arrangement of the triplets of pores is to a certain extent like that in typical recent Triplechinidæ, and the first or aboral pair (fig. 9, *c*) of each series of three in one line is, as in the recent forms, the adoral or actinal pair of a triple compound plate, and is situated much nearer the median line of the ambulacrum than the pair immediately above (fig. 9, *b*). The pairs are in oblique series of three,

slanting adorally and towards the interradia. But when a series of pairs is considered in relation to a compound plate it appears that there is really great arching, for the second and third pairs of pores in the linear series are the first and second pairs of the compound plate, whilst the third pair of the plate, or the adoral, belongs to the linear series immediately actinally, or they are much nearer the ambulacral median line.

The pair of pores which is in the abactinal part of a compound plate is the second pair of a triplet, and of course the third pair belongs to the middle plate of the combination. The second pair of the triplet of pores is nearer the interradium than the first pair, which belongs to the compound plate above; but the third pair, which is in the middle plate of the compound one, is nearest the interradium.

The peripodia of the pairs are rather close. The compound plates are low and much crowded, and there are no less than four of them in contact with an interradial plate slightly above the ambitus, where the diagrammatic sketch was taken. Thus as each compound plate consists of three plates combined, there are twelve in relation to an interradial plate.

In the specimen in Dr. Wright's collection the sutures of one of the ambulacra can be distinguished in a vertical series of four plates (fig. 9), the most apical of which and the most actinal bear tubercles, the two others being simply granular. The shape of the plates constituting the compound plates and the direction of the sutures differs in some of the compound plates; nevertheless there is no difficulty in seeing that the variation has been due to pressure from growth influencing plates which, under other circumstances, might have remained typical of *Diadema*. The arrangement of the component plates is not at all like that seen in *Echinus*, and the genus *Pedina* does not enter the family of the Echini proper.

Compound plate I.—The edges of the plate which are in the lines of the sutures between the plate and those immediately apical and adoral are, as is usual, transverse, and reach the median line at the reentering angle of the median zigzag.

The aboral plate (a') of the compound is a demi-plate which does not reach far beyond the poriferous half of the combination; and the adoral pore is on the adoral suture, which is curved with the convexity directed actinally.

The middle plate, a primary, carries the bulk of the tubercle and gradually increases in vertical measurement from the poriferous area to the vertical suture at the median line. It is bounded aborally by the demi-plate (a') and by part of the transverse suture, and it is bounded actinally by the edge and suture of the third plate, a primary (c).

This suture is curved, with the convexity aboral; it just touches the adoral part of the tubercle, and reaches the median line at a slight distance from the actinal and inner angle of the compound plate. The direction of the suture is that seen so commonly in the third plate of a triplet in *Hemipedina* and *Diadema*.

Thus the plate a' is a demi, plate b is a large primary, and plate c is a low and broad primary with an arched aboral edge.

Compound plate II.—This is composed of three primaries, of which the middle is the largest and occupies most of the plate near the median line. The plate is truly Diadematid in its shape and in the details of the sutures. Plate a is a low broad primary with its adoral edge curved actinally. Plate c is also a low and broad primary and the aboral edge is curved with the convexity placed towards the apex. Plate b is low at the poriferous area, nipped in and lower further towards the centre of the plate, and expanding considerably towards the median line.

Compound plate III.—This resembles the last; but the direction of the suture uniting the middle plate with the adoral plate is less curved and approaches a straight line.

Compound plate IV.—This is Arbacioid in shape and there is an aboral demi-plate (a'), a large middle primary plate (b), and an adoral demi-plate (c').

The middle plate, much the largest, carries the tubercle, and the whole of the vertical suture is in relation to it. The poriferous part of this hatchet-shaped plate (b) is low. Plate a' has its actinal edge much curved adorally, and the suture nearly reaches the median line, but the plate is a demi-plate.

Plate c', also a demi-plate, has its aboral suture curved with the convexity aboral, and it terminates short of the median line and at about the same vertical position as the suture of plate a'.

It is evident that *Pedina* is a well-defined genus, and that the situation of the sutures which are in the ambulacra is different from that seen in the family Echinidæ, and in the main resembles that of *Diadema* and *Pseudodiadema*.

The presence of the demi-plates fashioned after the Arbacioid type ally the form with *Hemicidaris*.

Genus Stomechinus, Desor.

The examination of the ambulacra of the typical species of this Oolitic genus shows that the plates are not arranged after the method which characterizes the true Echinidæ, of which the common *Echinus* is the type. The compound plates of *Stomechinus* are made up of primary plates combined and modelled after the *Diadema* type and not after that of *Echinus* or *Strongylocentrotus*.

Desor placed this Oolitic genus with *Echinus* and *Psammechinus*, and apart from the Diadematidæ.

The following is his diagnosis ('Synopsis des Echinides,' p. 124):—

Urchins of moderate size, subconical, with pores distinctly trigeminate as in the true Echini. Peristome large, profoundly cut, no longer decagonal, but in the form of a pentagon, the bifid angles of which correspond to the interambulacra. Spines striated longitudinally and small.

Stomechinus bigranularis, Lamk., sp., is the type, and its synonyms are *Echinus serialis*, Wright, *E. intermedius*, Agass., and *E. arenatus*,

Lamk. Desor notices that the amount of the cutting of the peristome differs in the species, and that in some specimens of the typical species this characteristic peculiarity is not so intense as in others. Nevertheless Desor, with his usual sagacity, seized upon the character which of itself distinguished this genus from its fossil allies. There are numerous species, and the specimens, so far as I can make out, have some other distinctive structures equally important with that chosen by the founder of the genus. These freshly noticed characters, well known to all writers, are of great importance now that the structure of the ambulacra is decided. Taking a good specimen of *Stomechinus bigranularis* from the Great Oolite, it is seen that the apical disk is small and compact, the basal plates project well into the median line of the interradia, and this line is very bare and well marked by the vertical suture. The triangular basals have large generative pores and alone form the anal ring. The radials are wide at the adoral edge, which is notched, and the optic pore is in that edge.

The tubercles of both areas are smooth, imperforate, non-crenulated, and not very unequal. The rows of tubercles diminish in numbers abactinally. The ambulacra are about one half of the width of the interradia above the ambitus, and at the peristome the ambulacra are nearly twice as wide as the interradia. The pores are in triplets, and above the ambitus the series of threes are very oblique and barely in arcs, but nearer the peristome they are more in arcs. The pairs are very numerous, and although there is a crowding towards the peristome still the pairs are in place.

Near the radial plate the poriferous plates are low and broad primaries. A little way down, and where the first large tubercle is seen, three primaries have combined to form a compound plate, low and broad. The adoral plate of the compound is a low primary with a slight aboral bend, and the aboral plate is also low and broad, and it has an adoral curve where it comes in contact with the middle plate; this is low at the poriferous part and expanded towards and at the median line. There are no demi-plates. The cuts are well developed, and yet in a form which will for the future be accessible in the British Museum these branchial slits are not so very distinctive; but there is always the great width of the ambulacra at the peristome and the remarkable diminution of the size of the interradia there.

It appears therefore that, bearing in mind the deep branchial cuts of some modern Diadematidæ; and the fact that these and other members of the family have bare median spaces, the peculiar shape of the component plates of the compounds, and the nature of the radial plates, *Stomechinus* must come amongst the Diadematidæ. Its position is clearly near *Pedina*, from which it is distinguished by the imperforate and non-crenulated tubercles, together with the deep branchial cuts.

Genus Hemicidaris, Agass.

The genus *Hemicidaris*, Agass., is very readily distinguished from

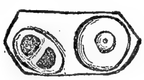
all others, according to its founder and Desor, by the structure of the ambulacra of the species. Desor remarks ('Synopsis des Echinides Fossiles,' p. 51, plates x. and xi.): "The distinctive character is found in the ambulacra, which, in one part of their length, particularly towards the base and sometimes as far as the ambitus, are furnished with true tubercles, which are smaller than those of the interradia, but which like them are distinctly crenulated and perforated." The generic diagnosis also notes that the poriferous zones are composed of two simple rows of pores which are frequently doubled at the peristome.

If the narrowness of the ambulacra and the multiplicity of the pairs of pores are added to the above very definite characters, all that has hitherto been recorded about the morphology of the ambulacra will be found to have been stated.

But the exceeding narrowness of the ambulacra above the ambitus, and the relatively narrow interporiferous area, coupled with the curving of long series of pairs of pores in relation to the great interradial tubercles placed near to the ambulacra, are necessary additions to the diagnosis. The species are numerous, and are Oolitic. Many of the forms from the Coral Rag are well preserved, and show structures which have hitherto escaped notice and which are of considerable classificatory importance.

In *Hemicidaris intermedia*, Forbes, and *Hemicidaris crenularis*, the plates of the ambulacra near the radial end are simple primaries. Each pair of pores is in a separate plate which either is ornamented with a tubercle or only carries one or more granules (fig. 10). There is usually an alternation of small tubercle-bearing and granular plates. The sixth plate from the radial plate, on ambulacrum II. zone *a* (fig. 10), specimen in Brit. Mus. no. 14122, may be taken as a type of the small primaries at this part of the

Fig. 10 (see p. 452).



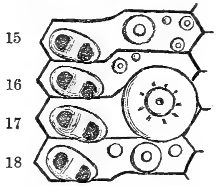
ambulacrum, where the plates are numerous and narrow. The position of the peripodium is usually slightly oblique and close to the interradial edge, near the adoral suture. The plate is broader than high, and much of it is covered by the tubercle. This is low and has a mamelon which is perforated. The granule-bearing plates of this part resemble that just described, except that a granule occupies the position of the tubercle. Usually there is but one granule. The tubercle-bearing plate intrudes upon the granule-bearing plate, which is placed aborally, so that this last is often the smaller of the two.

Besides the usual extension of the tubercle of the small primary plates very high up in the ambulacrum, an oblique direction of their adoral edge is often noticed; and it is evidently the result of the upward expansion of a plate which is situated adorally.

From the effects of the obliquity of the adoral edge, the part of the plate near the interradium is greater in vertical measurement than that towards the median line.

Numerous small and usually very low primary plates succeed, and in the ambulacrum under examination, wherever a granule-bearing plate is in contact adorally with a small tubercle-bearing one this last intrudes upon and deforms the other (fig. 11).

Fig. 11 (see p. 452).



The plates 15, 16, 17, and 18, of the same ambulacrum and zone, may be taken as typical of the greater part of the area halfway between the great tubercles at the ambitus and the radial plate.

Plate 15 is a low primary with a very small mamillated boss and three minute granules. The interporiferous portion is on a slightly higher level than the poriferous area, and the aboral edge of the plate below (plate 16) fits into a space which is produced by this want of conformity of level.

Plate 16 is of the usual height in the poriferous area, but it is forced up aborally by the expansion of the tubercle-bearing plate 17, situated immediately actinally to it, so as to conform at its adoral edge with the curve of the base of the tubercle. Hence this plate, which is very sparely ornamented with a granule or two, is almost linear towards the median line.

Plate 17 has a small tubercle which occupies nearly the whole of a much expanded interporiferous area, the increase in growth being apical. The next plate, 18, is a low primary with granules, and it is not much deformed by the slight adoral extension of the above-mentioned tubercle. All these plates are primaries.

Nearer the ambitus the fusion of primaries, forming compound plates with two pairs of pores, becomes evident. Thus at plates 35, 36, and 37 (fig. 12), this is well seen.

Fig. 12 (see p. 452).

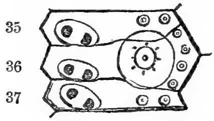


Plate 35 is a primary, or, rather, was one before its adoral edge united, organically, with the aboral edge of the plate 36, and before

this union produced a symmetrical plate towards the median line. The tubercle of plate 36 intrudes on plate 35, the adoral suture of which crosses the boss to reach the median line not far from the apical angle of the compound plate: this suture is curved, with the convexity directed adorally. A few granules are placed between the tubercle and the median line, and upon the apical part of plate 35.

On comparing plates 35 and 36 with plates 16 and 17, it would appear that the resisting power of the plate 35 was greater than that of plate 16; but this is the first evidence we have of the direction of the aboral plate of a combination. It is important to observe that the poriferous area of plate 35 is higher in measurement than the part close to the median line.

The tuberculiferous area of plate 36 is much larger than the corresponding poriferous area. The next plate, 37, is a small low primary, with granules, and the first step towards its organic connexion with plate 36 is the symmetrical arrangement of the granules in conformity with their place and trend in the two other plates 35 and 36, which certainly do form a double-pored combination.

The structure of the plates immediately aborally to the first large tubercle at the ambitus, counting from the radial plate, is simple as a rule, and differs in a remarkable manner from that of the great tubercle-bearing compound plates. Taking the Amb. III. of the species of *Hemicidaris*, and the zone " a," it will be noticed that the small compound plate placed aborally to the great tubercle, consists of three low primary plates united to form a symmetrical combination (fig. 13)*. The tubercle which is placed on this compound

Fig. 13 (see p. 452).

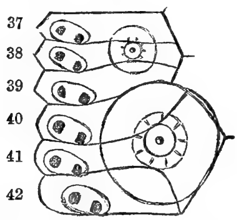
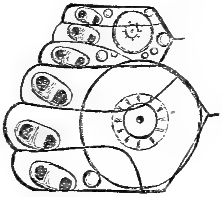


plate is small, and its boss is crossed, from the poriferous area to the median line, by the sutures of the aboral and adoral plates (37 & 39) where they are in contact with the edges of the central plate, which usually has the mamelon upon it (38). The line of the sutures is almost transverse in most instances; but it may happen that the adoral plate of the combination is so jammed by the huge tubercle of the plate immediately on the actinal side, that it becomes a demi-plate, because it cannot reach the median line (fig. 14).

The following is the construction of a large tubercle-bearing plate at the ambitus (figs. 13, 14).

* Specimen 24122, British Museum.

Fig. 14 (see p. 452).



The tubercle covers nearly the whole of the three plates which compose the compound plate, and even the peripodia are on its slope.

The tubercle, as is well known, is large and tall, has a sloping boss, a wide crenulated ridge and groove, and a large perforated mamelon. There are three pairs of pores surrounded by as many peripodia in immediate relation with the plate, and they are rather distant and in an arc. (A pair situated adorally to the others is in connexion with the compound plate placed immediately actinally. Again, a pair which is on a line with the aboral edge of the tubercle belongs to the plate above.) On examining most specimens the only trace of a suture between any of the component plates is seen very generally as a depressed line on the side of the boss towards the median line of the ambulacrum and passing towards the aboral and inner angle of the compound plate or rather of the tubercle. The direction of the line is apical and to the median line, and it reaches this last either slightly or considerably below the aboral angle of the compound plate at the vertical suture. But in many weathered specimens there is another and distinct suture visible, and it passes actinally from the crenulated edge over the adoral face of the boss, and it may reach the transverse suture with a gentle curve. On the poriferous side of the tubercle the first-mentioned suture is seen to be in relation with the highest of the three peripodia of the plate, to commence in the line of groove passing adorally to the obliquely placed first pair of pores, no. 40, and to reach up the side of the boss to the crenulated ridge, and then to cross the boss towards the median line. The direction of this suture may be in a right line or in a slight curve with the convexity looking actinally. The suture joins the aboral and central plates of the triplet, and it leaves the mamelon adorally and pursues a more or less oblique course. It is clearly touched by the adoral pore of the pair.

The shape of the suture and its direction determine to a great extent the shape of the aboral plate of the combination, and this is a primary plate with the poriferous area higher in vertical measurement than the opposite extremity, and with the intermediate part the highest of all.

The next pair of pores, situated adorally to the last, are also obliquely placed, and on the edge of the boss (no. 41), and the adoral pore is in contact with a suture which passes inwards and up

the flank of the boss adorally to the crenulated ridge, and which then turns with a more or less wide angle to reach the suture between the tubercle-bearing plate now under consideration and that placed immediately adorally. But the suture does not reach the median line of the ambulacrum, for the plate (42) which it bounds aborally is a demi-plate *.

This demi-plate, the third or adoral, of the compound tubercle-bearing plate (no. 42), varies in size in different tubercles and is always highest at the region of the boss.

The central plate (no. 41), which is bounded actinally by the suture first described which crosses the tubercle obliquely, and also by that just noticed, is very large and is a primary. It is rather low at the poriferous area, but the height increases on the surface occupied by the mamelon, and all the inner part of the combination-plate is occupied by it towards the median line, except a small portion close to the aboral and inner angle which belongs to the highest of the triplet. Thus the great tubercle-bearing compound plate is composed of a large intermediate primary, a smaller aboral primary, and a large demi-plate (sometimes a primary) which is the adoral of the three.

It is interesting to note that in shape the aboral plate resembles the corresponding plate in the genus *Diadema*, and that the adoral has frequently the outlines of the corresponding plate in *Cœlopleurus*, Duncan and Sladen, op. cit.

All the great tubercle-bearing plates of *Hemicidaris* show the details just described, and if there is any variation it depends on the position and nature of the plate towards the peristome where the sutures come closer together.

In the majority of ambulacra the next three plates, situated adorally to those just described, carry a large tubercle resembling in shape that noticed above, but smaller. The plates form a compound one, and the lines of their sutures and therefore their shapes are the same as in the compound plate just noticed. The peripodia are in an arc, and are three in number, and the aboral plate of the triplet is a broad and low primary resembling that of the first tubercle-bearing plate; the second is also a large primary, and the third or adoral plate is a demi-plate.

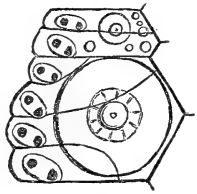
The next compound plate is also a triplet, and so are all the others down to the peristome. The pairs of pores and their peripodia are closer, and the arcs are interfered with in consequence of growth and pressure; but the three peripodia of a tuberculiferous plate can always be distinguished, although the second peripodium of a series may be almost excluded. There is no addition of plates or pairs of pores, and the position of the pairs corresponds with that observed and described by Lovén in *Strongylocentrotus*, although the explanation he gave will hardly meet the instance of *Hemicidaris*.

An important exception to the rule regarding the regular sequence of the ambulacral tubercles, occurs in some specimens. Thus in a

* There is some variation in different specimens and the suture does reach the median line in some (see fig. 13).

well-preserved specimen the first great tubercle-bearing compound plate of ambulacrum III., zone "a," is followed apically by granule-bearing plates, two of which clearly form a compound plate; but the third or adoral one seems to have become jammed into the aboral face of the tubercle-bearing plate below (fig. 15).

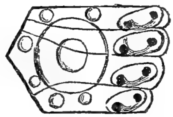
Fig. 15 (see p. 452).



It is evident that there are four plates in this compound one, and that the existence of the small demi-plate is due to the great pressure to which it was subjected whilst a primary.

Hemicidaris granulosa, Wright, a species from the Inferior Oolite, of which there is a specimen in the Museum of Practical Geology, Jermyn Street, has the ambital compound plates made up of four primaries. The three placed actinally present the typical *Diadema*-arrangement, and the aboral plate is a low and broad primary (fig. 16).

Fig. 16 (see p. 452).



The same arrangement of four plates in a compound one occurs in *Hemicidaris Wrighti*, Desor, from the Great Oolite.

In small and immature specimens of *Hemicidaris intermedia* the plates which bear the great tubercles at the ambitus are made exactly after the fashion of the simplest *Pseudodiadema*.

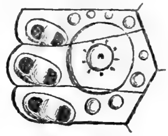
In a specimen of *H. pustulosa*, Agass., in the Museum of Practical Geology, the suturing of the plates at the peristome is perfectly visible. The pairs are in triple series, and the plating is like that of the simple *Pseudodiadema*.

It is certain that there is no trace of a demi-plate in these last three species.

It is possible that the existence of a demi-plate in some of the specimens of *H. intermedia* may be an individual peculiarity; for in the specimen already noticed with a demi-plate jammed into the aboral part of a compound plate, there is another anomaly.

The compound plates begin nearer the radial plate than is usual, and the plates of zone "a," ambulacrum III., numbered 31, 32, and 33, form a triplet (fig. 17).

Fig. 17 (see p. 452).



It appears, then, that in the genus *Hemicidaris* the multitude of small primaries is succeeded by doublets or triplets and the great tubercle-bearing plates. These are either triplets after the *Diadema*-type, more or less modified, or have four pairs of pores, the additional pair being in a low primary, which has been joined to the aboral edge of a compound plate, or in a demi-plate (fig. 15). The influence of the growth of the large tubercles upon the spreading of the middle plate and the curvature of the adoral and aboral plates is very evident.

Finally, it appears that the arrangement of the triplets when crowded at the peristome is not very remote from that seen in some abactinal parts of the ambulacra of species of *Pedina*.

Genus Diplopodia, McCoy.

Small immature specimens of such types as *Pseudodiadema versipora* show a doubling of the pairs of pores near the apex unlike the condition which prevails in small specimens of the true *Pseudodiadema*, which are unigeminal. This species, according to the principles which govern the classification of the recent Echinoidea, cannot remain in the genus *Pseudodiadema*, and must come within *Diplopodia*.

Other forms are said to become diplopodous only at adult age, and this has been considered a sufficient reason for not placing them out of the genus *Pseudodiadema*; but it was forgotten by the adopters of this reasoning that zoologists must consider the adult development of a form, and not its immature condition. A form with bigeminal pairs of pores in the upper part of the ambulacra is a *Diplopodia*; and as yet I must confess not to have been able to recognize any forms about to become diplopodous. We can only deal with absolute facts, and not with presumptions.

The question arises, leaving out the bigeminal nature of the pairs, Are the other generic characters sufficient to separate *Diplopodia* from *Pseudodiadema*?

It appears that the diplopodous condition near the apex is accompanied by crowding and doubling of the pores near the peristome, and, as a rule, by some departure of the pairs of pores in plates at the ambitus from a regular line or arc.

Moreover, the structure of the part of the ambulacra near the radial plates differs in the diplopodous series from that seen in the true *Pseudodiadema*. There is not that blending of the small plates into compound ones which is a character of *Pseudodiadema*.

When there is such a combination as in *Diplopodia Roissyi*, Cott.

(Echinides du Départ. de la Sarthe, par Cotteau et Triger, 1859, plate xxxiv. fig. 5), the propriety of calling the species a *Diplopodia* is doubtful; for the pairs of pores resemble in their arrangement those of *Pedina*.

The genus *Cyphosoma*, Agass., is characterized by the doubling of the pairs of pores near the apex; and this character is certainly developed with varying age according to the species. But the adults have the character, and the forms which are without it are placed in the genus *Coptosoma*, Desor. The alliance of *Cyphosoma* to the *Pseudodiadema*-group is evident from the common external characters, and there are points in the structure of the ambulacra which unite the genera and at the same time refer to the Triplechinidæ.

Diplopodia versipora, Phill., sp., non *Diplopodia subangularis*, McCoy.

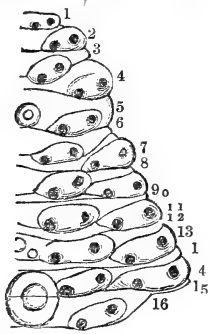
This species, usually attributed to *Pseudodiadema*, is very familiar to the students of the fossils of the Coralline Oolite, and it has been figured by Dr. Wright (op. cit. plate vii. fig. 4).

The nature of the construction of the ambulacra has not been given, except in a general manner.

The diplopodous condition of the pairs of pores is well worthy of study, and it can be examined in a specimen in my possession.

Taking one of the zones of an ambulacrum, it is seen that the first plate next to and in contact with the radial plate is a low and narrow primary, with the adoral pore close to the median line of the ambulacrum, and the aboral placed obliquely to it, the first-mentioned pore being also on the line of suture between the first and second plates (fig. 18). The second plate is at least twice the size of

Fig. 18 (see p. 452).



the other, is slightly higher and much broader, and the adoral pore reaches the suture between this and the third plate, being placed almost directly actinally to the aboral pore of the first plate. The aboral pore is far out of the vertical line of the corresponding pore of the first plate. Both of the plates are primaries, and do not form a compound plate. The third plate is high at the median line and very low at the ambulacro-interradial suture; the

aboral edge is transverse, and the actinal is oblique from the median upwards and outwards. The pair of pores is decidedly oblique, and the aboral pore is on a vertical line with the adoral pore of the second plate.

Plate four is a primary with a large expansion in the poriferous part and a very low and almost linear interporiferous area.

Its pair of pores are nearer the interradium than those of plate three. Plate five is a primary, its shape is irregularly rectangular, and it is larger than any of the plates noticed; the pair of pores can hardly be said to be one of the inner set, and there is a small tubercle close to the median line.

Following the rule which has been observed in recent forms, this tubercle, being bound to grow in all directions, prevented the adoral growth of the plate immediately above.

Plate six is low externally and higher somewhat towards the median line. Its pair of pores are in a peripodium, and they belong to the inner row. Plate seven, also a primary, is largest close to the interradial edge, where the pair of pores are, and it is almost linear towards the median line. It is decidedly broader than the other plates hitherto noticed; and indeed every plate in this region becomes broader as the distance from the radial plate is increased.

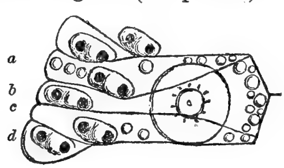
This plate is one of the outer set.

Plate eight is very low externally, swells at the peripodium, and is higher at the median line; its pair of pores belong to the inner series. Plates ten, twelve, and fourteen belong to the same series as plate eight, and are formed after the same plan; they are all primaries, and have low and almost linear outer parts; the pores belong to the inner set and the plates are highest at the median line. On the other hand the plates nine, eleven, thirteen, and fifteen are upon the same type as plate seven, and belong to the outer series, with low and linear portions near the median line and enlarged poriferous zones.

In a young specimen the alternation of different-sized plates, all of which are primaries, extends at least to the twenty-fourth plate. Then the primaries become combined into a compound plate, some being blocked out, however, from the median line and becoming demi-plates. This condition is seen in adult as well as in young specimens, and just where the bigeminal pores begin to diminish and to be replaced by simple pairs.

The first compound plate is a tubercle-bearing one in the specimen under examination; there are four pairs of pores belonging to it and they are in double series (fig. 19). (The upper two pairs do not belong to the plate.)

Fig. 19 (see p. 452).



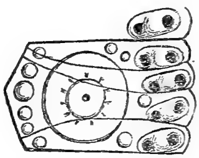
The aboral pair, *a*, like the others, is oblique and in a peripodium. It belongs to the inner series, and is separated from the interradial suture by a rather large space, which is ornamented. The adoral pore of the pair is on the line of suture between the poriferous plate and the next in adoral succession, and the suture is curved with the convexity adoral, so as to reach the flank of the boss and thence to pass inwards and aborally, to the median line, and close to the aboral angle of the geometrical compound plate. This plate, with the aboral pair of pores, is of the *Diadema*-shape; but the pores are remoter from the interradium than is the case in the genus *Pseudodiadema*.

The next pair of pores, *b*, placed actinally, is close to the interradium, belongs to the outer set, and is in a peripodium. The plate is nipped in just adorally to the position of the first pair, and it then expands so as to include the mamelon and much of the boss and form the greater part of the compound plate near the median line.

The adoral pore of the pair is in contact with the suture at the edge of the plate below, which is curved with the convexity aboral, and the suture reaches the median line slightly aborally to the actinal angle of the compound plate. This suture is the limit of the third plate, *c*, of the combination, and this has its pair of pores forming part of the inner series. The adoral pore of the plate (*c*) is on the transverse suture placed actinally to the compound plate. Finally the actinally placed plate, *d*, is a demi-plate which may seem to have nothing to do with the combination; but it forms a small portion of it, and the pair of pores belongs to the outer series. The plate does not reach further towards the median line than the position of the adoral pore of the pair of the third primary plate. There is no doubt that such a combination is not found in the genera *Diadema* and *Pseudodiadema*.

Nearer the ambitus, or at that spot, the usual number of pairs of pores to a compound plate is four, the line of the pairs is simple, and the distribution of the composing plates is as in the species of *Hemicidaris*, that is, there are four primaries, of which the third is the largest (fig. 20).

Fig. 20 (see p. 452).



In some plates, however, there is a demi-plate; and then the structure rather recalls the compound plates of the *Plesiodiademata*.

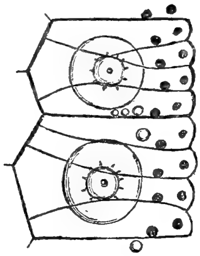
The doubling of the pairs of pores towards the peristome is almost a copy of that seen near the radial plate; there is no addition

of new plates, and the triplets are all reducible to their normal position from which growth-pressure has forced them, on the principle elaborated in the instance of *Strongylocentrotus* &c.

In very young examples of *Diplopodia versipora* the doubling of the apical pores is seen, and the large compound plates are of the *Diadema*-type.

In *Diplopodia Malbosii*, Desor, of Cretaceous age, the replacement of the ordinary demi-plate of the ambital plates by a low and curved primary is not uncommon, and both conditions may be seen in the same ambulacrum (fig. 21).

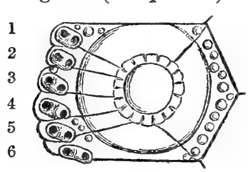
Fig. 21 (see p. 452).



Genus Cyphosoma, Agass.

The genus *Cyphosoma* is diplopodous; but the structure of the ambulacra is different from that in *Pseudodiadema* and *Diplopodia*. Many of the species are polypores, and four, five, or six plates may enter into the construction of a compound and tubercle-bearing plate. *Cyphosoma Königi* is a very good example, and well-weathered specimens are common. They frequently show the line of partition between the component plates of the compound ones, or rather the lines may be distinctly seen passing from the adoral pores of the oblique peripodia up the boss, and more or less obliquely towards the mamelon. In the majority of specimens two sutural lines are seen on the flank of the boss which is opposite the peripodia and near the median line of the ambulacrum (fig. 22). These are perfectly visible in most cases. See figs. 22–25.

Fig. 22 (see p. 452).



One of these, that actinally situate, is seen to come from the

adoral and inner shoulder of the crenulation on the boss, and to pass obliquely actinally and towards the median line of the ambulacrum. The line forms an arch, the chord of which is the transverse suture at the actinal edge of the compound plate. The other line starts from the abactinal and inner shoulder of the crenulation, and passes obliquely abactinally and towards the median line.

Both of these well-marked lines are sutural, are between certain plates, and they both reach the median or vertical suture of the compound plates. The adorally situated line is the aboral limit of a primary plate, just as the aboral line is the limit of the aboral primary plate of the combination. A line can be traced from the first (the most abactinal) peripodium of the compound plate to the part of the crenulation at the aboral and outer shoulder of the boss; and there is little doubt of the continuity along the abactinal edge of the mamelon of the whole actinal line. The last peripodium but one of the compound plate, counting from the abactinal peripodium, has a line passing from the adoral pore obliquely inwards and towards the nearest shoulder of the boss, and this corresponds with the aboral edge of the actinal primary plate of the combination. Hence there is an adoral primary with a bent or curved edge, and there is also a similar actinal primary. There is also a middle primary, the direction of the arching of the plates being opposite.

In the compound plates with six peripodia there is an aboral primary, an adoral primary, and there are also lines of suture passing to the base of the mamelon from the 2nd, 3rd, & 4th peripodia (besides those from 1 & 5). But, as in the instances of the compound plate with five peripodia, there are no signs of sutural lines passing down the inner flank of the boss corresponding to the 2nd, 3rd, & 4th lines on the outer or interradial side.

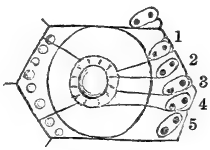
There are, then, three demi-plates to the compound plates with six peripodia, and therefore there is a third primary plate, as there must also be in the combination with five peripodia.

The position of the third primary is readily made out on the part of the tubercle-bearing plate near the median line, for it must relate to the expansion that exists between the inner ends of the aboral and adoral plates. But its position near the peripodia is a matter of doubt, in consequence of the homogeneous condition of the mamelon. The direction of the part of the plates close to the peripodia is, however, a somewhat correct guide where to look for the primary between the others. Certainly the first pair of pores is in relation to the aboral primary, and it is clear that the second pair is in a demi-plate. In most plates the narrow part between the demi-plate just noticed and the next line in adoral succession, passes either directly transversely or slightly actinally and towards the boss, and it is this direction which opens out two possibilities regarding the position of the middle primary.

In the compound plates with five component plates, the peripodia (fig. 23, nos. 1, 2, 3, 4) have sutural lines represented by grooves passing from their adoral pores to the mamelon, but not so the fifth. Of these lines, nos. 2 & 3 pass up the boss to the crenulated groove

and are then lost at the very base of the large imperforate mamelon. The lines converge, and as the other lines of union of the plates nos. 1 & 4 already mentioned also converge, a very marked feature results; but there are no lines in continuation of those numbered 2 & 3 to be seen on the part of the tubercle near the median line and between the two very distinct lines already noticed. Consequently there must be at least two demi-plates, also the aboral and adoral primary plates, besides a middle primary.

Fig. 23 (see p. 452).



There is sometimes an appearance in compound plates consisting of five plates, as if the third plate from the abactinal edge were the middle primary (fig. 23). The fourth plate appears to be a demi-plate which joins on to the fifth or the adoral primary.

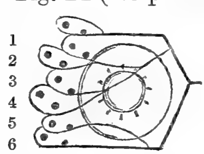
This arrangement would be very exceptional amongst forms of Echinoidea with many demi-plates; nevertheless the position of the middle primary would be that seen in the Diadematidæ of the recent fauna, with the addition of a demi-plate placed aborally and adorally to the middle plate.

It is also to be remembered that Alex. Agassiz gives a diagram of *Phymosoma* (*Cyphosoma*) *crenulare*, Agass., in the 'Revision of the Echini,' plate vi. fig. 2, in which the middle primary has a demi-plate on either side of it, and the arrangement is the same as that now under consideration. But the species mentioned by Agassiz is not a *Cyphosoma*, for the abactinal pores are not diplopodous; the form must come within a new genus.

This diplopodous condition of the pores must be considered in investigating the formation of the ambulacral compound plates.

In a specimen of *Cyphosoma Königi*, Mant., there is a compound plate higher than the ambitus, in which the diplopodous condition lingers on, and there are three double sets of pores (fig. 24).

Fig. 24 (see p. 452).

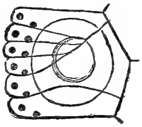


The rule is followed in the compound plate, with regard to the succession of the pairs, which prevails more abactinally and where the double sets are not united in compound plates. The outer pairs of pores are in plates which are crushed and crowded out from the

median line of the ambulacrum by the growth of the inner set. Plate 1 of the compound is in relation to an inner pair of pores and it is the aboral primary. Plate 2 is one of the outer set and it is a demi-plate which only reaches a very slight distance from the pair of pores. Plate 3 is in relation to an inner set of pores, and it is larger than the last, but still it does not reach the median line; it is a large demi-plate. Plate 4 is a small demi-plate and it belongs to the outer series of poriferous plates. Plate 5 is one of the inner series and is a large primary, the middle one of the three primaries. Plate 6 is one of the outer set and is a large demi-plate or possibly a primary. It is of the usual shape of the adoral primary in compound plates situated lower down.

In a compound plate with six plates, in Dr. Wright's collection, of which I took a diagram (fig. 25), there is little doubt that the diplo-

Fig. 25 (see p. 452).



podous condition must be considered as really affecting the relative dimensions of the plates. In the specimen (*C. Königi*) the existence of an adoral and aboral primary is evident, and there is a large middle primary; but it is in relation to the fifth pair of pores. The second, third, and fourth plates are demi-plates, and are arranged after the fashion of *Strongylocentrotus*, as described by Lovén. This is the same arrangement as is seen in the diplopodous compound plate.

Under the circumstances the Cyphosomoid type of ambulacrum differs from the *Diadema*-type in its simplest expression, and also from the diplopodous type exemplified in *Diplopodia versipora*.

The Cyphosomoid type may be said to unite the Diadematoid and the Echinoid types.

IV. Conclusions relating to the types of Ambulacra.

It may be now assumed from the results of former observations, and from the consideration of the structures noticed in this essay, that there are certain well-defined types of ambulacra in the regular Echinoidea.

1. The Cidaroid type. All the plates of the ambulacra are primaries, and they do not combine to form compound plates.

2. The Diadematoid type. The newest plates are primaries, and at greater or less distance from the ambitus three primaries unite to form a compound plate, the middle plate of the three being the largest. (Journ. Linn. Soc. Zool. vol. xix. p. 95, 1885.)

3. The Arbacioid type. The newest plates are primaries, and at varying distances from the ambitus three primaries unite to form a

compound plate, the middle plate being the largest, and the two others are smaller and become demi-plates in consequence of the growth-pressure exercised by the great tubercle of the compound plate. (Journ. Linn. Soc. Zool. vol. xix. p. 25, 1885.)

4. The Echinoid type. This has primaries near the radial plate and then compound plates are seen of three or more plates combined.

The middle plates are demi-plates and the primaries are aboral and adoral, or all the aboral plates may be demi-plates. (Lovén, Études, and Monogr. of the Fossil Echinoidea of Sind, Fasc. Gaj Series, Pal. Indica, Ser. xiv. 1885, Duncan & Sladen, *Hipponoe.*)

5. The Cyphosomoid type. This unites the Echinoid, the Diadematoid, and the next or diplopodous type.

6. The Diplopodous type. The primaries near the radial plates are, in young forms as well as in the adults, arranged in a double row; and this condition reaches to a greater or less distance towards the ambitus or even to the peristome. There is great diminution of the height or absorption of the non-poriferous parts of some plates.

It is evident that while the Cidaroid type never varies, the Diadematoid and Arbacioid types tend to the Echinoid type in some instances on account of the formation of one or more demi-plates in a compound plate.

It is also interesting to notice that the Arbacioids, which came later in time than the Diadematidæ, have the usual simple Cidaroid arrangement in the young plates near the radial plate, and at some distance down a plate or two on the Diadematoid type. Then come the true Arbacioid compound plates.

The demi-plate came in with the *Pseudodiademata*, and became of importance in the construction of the compound plates of *Cœlopleurus* and the later genera of Arbacioids.

Finally the differences in the construction of the ambulacra necessitate the separation of the genera *Plesiodiadema* and *Diplopodia* from *Pseudodiadema*.

The only notice that I have been able to discover of the remarkable disposition of the plates of the Diadematidæ is in the description of *Heterodiadema ouremense* by De Loriol (Recueil Zool. Suisse, t. i. no. 4, Sept. 1884, p. 626). There is a drawing given and a description of the triple plate, and they conform to the type of the true *Diademata*. I did not see this communication of M. de Loriol until the essay I have read before the Geological Society was completed. Cotteau gives indications of some sutures in many of his plates on the Echinoidea, but he does not describe the sutures or pay attention to them.

DESCRIPTION OF THE FIGURES IN THE TEXT.

Fig. 1. Two compound plates of *Strongylocentrotus*, after Lovén (p. 421).
2. A compound plate of *Hemipedina Jardini*, Wright (p. 423).
3. A compound plate of *Hemipedina marchamensis*, Wright (p. 424).
4. A compound plate of *Hemipedina tuberculosa*, Wright (p. 425).
5. Part of the ambulacrum near the ambitus of *Pseudodiadema hemisphæricum*, Lamk. (p. 428).

Fig. 6. A compound plate with a demi-plate of the same form (p. 429).
7. Two compound plates of *Pseudodiadema depressum*, var. (p. 430).
8. Two compound plates at the ambitus of *Plesiodiadema Michelini*, Agass., showing the numerous primary plates (p. 431).
9. A diagram of four compound plates of *Pedina Smithi*. *a*. Primary plates, *b* & *c* also primaries. *a'* & *c'* are demi-plates (p. 433).
10. A single primary of *Hemicidaris intermedia* (p. 437).
11. More or less deformed primaries (p. 438).
12. The first compound plate from the union of two primaries, a third and ununited primary being beneath (p. 438).
13. Two compound plates of *Hemicidaris crenularis*. The lower plate carries a great tubercle. Amb. iii. (Brit. Mus. No. 24122) (p. 439).
14. Two compound plates of *Hemicidaris crenularis* (p. 440).
15. Two compound plates of *Hemicidaris intermedia*: the adoral plate of the upper series has been formed into a demi-plate by growth-pressure, and now forms a part of the lower plate (p. 442).
16. A plate of *Hemicidaris granulosa*, showing affinities with *Plesiodiadema* (p. 442).
17. The first triplet of a specimen of *Hemicidaris* (p. 443).
18. The ambulacrum near the radial end of *Diplopodia versipora* (p. 444).
19. A compound plate of *Diplopodia versipora*, showing the persistence of the diplopodous arrangement (p. 445).
20. A compound plate of the same species with a low primary plate (p. 446).
21. Two plates of *Diplopodia Malbosii*, Desor. In the actinal there is the arrangement of *Plesiodiadema*, and in the other that of the Liassic Diadematidæ (p. 447).
22. A compound plate of *Cyphosoma Königi*, Mant., with six plates showing the numerous sutural lines on the poriferous side and the two lines towards the vertical suture (p. 447).
23. A compound plate of the same species with five plates and the sutural lines (p. 449).
24. A compound plate from the same specimen showing the relics of the diplopodous arrangement, and indicating the alternation of large and small plates and the direction of the sutures (p. 449).
25. A diagram of the plates and sutures in a specimen of *Cyphosoma Königi*, in the collection of the late Dr. Wright, F.R.S. (p. 450).

All these figures are magnified and more or less diagrammatic copies from nature.

Discussion.

Mr. W. Percy Sladen spoke of the importance of this communication, both on account of its explaining points which were little known and for its bearing on classification. A. Agassiz and Lovén have cleared up some of the difficulties in the classification of the regular Echinoids, but probably this contribution to the question would prove of still more importance. He had himself had the opportunity of following and confirming Dr. Duncan's observations, and expressed the strongest conviction that the structures indicated would shortly be shown to be of higher importance from a morphological point of view than had hitherto been supposed.

Prof. Seeley said that it seemed to him that this was a most important contribution to zoological palæontology, and its importance would be more clearly seen as its bearings on classification and evolution were traced out. It showed the effects through generations of crushing upon the characters of the ambulacral plates. The question then arises: As the plates are crushed together, forced

downwards and partly absorbed by pressure, why do they group into certain definite associations of plates and half-plates? Prof. Seeley had for many years had the opportunity of studying what had been written upon this subject, and he thought that much light had been thrown upon it by this paper. He believed the growth of the interambulacral plates had much influence on the form of the compound plates of the ambulacral areas.

Dr. Murie considered that the paper was of great value from its recognition of physiological facts, and its indication of their bearing upon the theory of the evolution of organized forms.

Mr. Etheridge called attention to the work of Dr. Wright on the characters furnished by the ambulacra in the study of the regular Echinoidea, and showed that Dr. Duncan's contribution had brought into view the value of those investigations. The ambulacra were of vast importance in classification, and they were most difficult to examine. Lovén's work, too, was of very great importance.

The Author, in reply, said that he had been much indebted to Lovén's investigations. Doubtless the action of growth-pressure which he had referred to as "crushing," resulted in part in producing geometrical figures, the interambulacra acting as "buffers" to the ambulacral plates. The gradual formation of more complicated types was very interesting. The increase in the number of pores above the ambitus in the recent Diadematidæ certainly meant increase in power of respiration.

32. Evidence *of the* Action *of* Land-Ice *at* Great Crosby, Lancashire. By T. Mellard Reade, Esq., C.E., F.G.S. (Read May 13, 1885.)

(Abridged.)

In previous papers* I have described a deposit of rubble-débris and red sand lying on the Triassic rocks and underlying the Low-level Boulder-clay and sands in the neighbourhood of Liverpool, which I suggested was due to the grinding and crushing action of land-ice. I also pointed out that where this deposit did not occur, the rocks, as is well known, are usually polished, grooved, and striated. Until lately no opportunity has occurred of testing the validity of this view by reference to any other than sandstone rock that such land-ice may have moved over †.

In October 1884 I described, in the 'Geological Magazine,' a section of Keuper marls at Great Crosby previously unknown, and since then I have made frequent observations of the upper part of the marls in relation to the Low-level Boulder-clay that overlies them.

From time to time as the excavations have proceeded, it became clearly apparent that the upper part of the marls had been from some cause or other much disturbed. There were imbedded in it large angular and sometimes nearly square blocks of sandstone. These were not merely pressed into the surface, but actually imbedded in the marl at all angles. In the undisturbed marls are well-defined bands of a harder nature, and one of these bands was at one place broken up and contorted, the fragments displaced, and irregularly forced into and amongst the worked-up softer marls or shales (see fig. p. 455). This was very striking, as the band continued in an undisturbed condition towards the south-west ‡.

As fresh faces were disclosed by the progress of the excavations, it could be distinctly seen that in some cases the upper soft fissile marls had been forced up into contortions. The thickness of the disturbed bed was from 3 to 4 feet.

The imbedded sandstone blocks were of two kinds: one a very fine-grained grey rock slightly micaceous; the other composed of coarsely rounded grains, mostly quartzose. They are evidently sandstones belonging to the Keuper series, though not found in this pit *in situ*. Neither are they exactly like any of the Lower Keuper sandstone beds found in the quarry at Little Crosby, about one mile and a half to the north-west. I am of opinion that they belong to beds underlying those at the bottom of the pit, which at the north-east side approach in structure the coarser of the two sandstones.

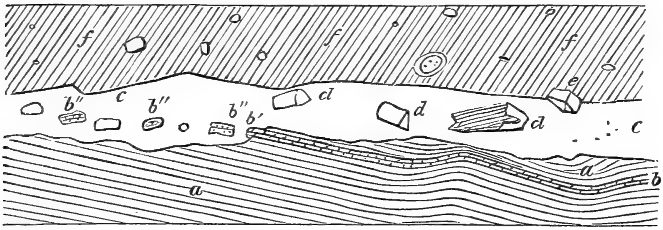
* "Drift deposits of the N.W. of England," Quart. Journ. Geol. Soc. vol. xxx. p. 27; and vol. xxxix. p. 122.

† Mr. Strahan, in his Survey memoir of the 'Geology of the Country around Chester,' 1882, says "There is evidence of the passage of a heavy body over the ground in the crushing and drawing out of soft beds as if by pressure" (p. 29).

‡ The contortion of the beds below the eroded line in the section I consider to be due to earth movements.

It was not until several examinations were made that I was able to discover any striations on the imbedded sandstone. At last I detected them on a block measuring 4 ft. × 2 ft. 10 in. × 1 ft. 9 in. in extreme dimensions. On washing the marly clay off the face, very good parallel groovings were disclosed, running along the plane of bedding and the longer axis. With this clue I soon saw that the undersides of most of the stones were polished smooth, and others irregularly scratched.

Section at Mowbrey Brick and Tile Works, Great Crosby.



a, a. Grey shaly Keuper marl. *b.* Hard band in Keuper marl broken off at *b′*. *b″, b″.* Fragments of hard band, *b*, scattered through and imbedded in the "kneaded-up" marl. *c, c.* "Kneaded-up" marl, that is the Keuper marl or shale, worked-up into a grey clay. *d, d.* Blocks of sandstone, some fine-grained and strong, others coarser in grain and often smoothed and striated, in one instance strongly fluted. *e.* Half-imbedded block *f.* Low-level Boulder-clay (marine), containing far-travelled erratics and broken marine shells (brown in colour).

Specimens of the undisturbed marl and the kneaded-up marl were sent to Mr. David Robertson, F.G.S., who kindly examined them microscopically. No organisms were found in either, and they were practically of the same constitution. No far-travelled erratics, nor any stones or material that could not be referred to the Keuper formation could be found in the kneaded-up marl. Even the half-imbedded stones were, in all cases that I have seen, Keuper sandstones. The true erratics are confined to the overlying Low-level Boulder-clay. This clay is so distinctive a deposit that it is only necessary to say that here as elsewhere it contains fragments of marine shells, and is undoubtedly of aqueous and marine origin.

Importance of the Discovery.—The evidence of these disturbed shales is of importance taken in connexion with the prevalence in South-west Lancashire and Cheshire of glacial markings and smoothed rocks.

At the present moment (March 1885) is to be seen a very fine example of polished and striated rock at Flaybrick Hill, Birkenhead, Cheshire, a veritable *roche moutonnée* which has only just been bared of its covering of Low-level Boulder-clay.

It has, however, been a moot point with local geologists whether these markings are due to land- or floating ice. I have myself always considered that the weight of evidence preponderated in favour of land-ice, though there are some facts apparently irrecon-

cilable with that view. The phenomena described in this paper seem to me stronger evidence in favour of the land-ice hypothesis than any I had previously seen. It seems to me next to impossible that the disturbance of these shales could have been effected by floating ice in any form, and the entire absence of extraneous material in the "kneaded-up marls" lends further force to this view.

It is not easy to get the exact direction of the dip of the shales; but it is from north to south or between that and north-east to south-west. It follows from this that the lower beds must crop up towards the north, though the country is so buried in a mantle of Low-level Boulder-clay that the outcrop is not seen. If the disturbance of the shales were due to land-ice coming from the north or north-west (the nearest striæ so far recorded are at Little Crosby quarry, 22° W. of N., and opposite the Police Station at Great Crosby, 40° W. of N.), the outcrop of the lower beds consisting of sandstones would be torn up and pushed over and into the kneaded-up shales at all angles, and this so far corresponds with the facts described. Some of these rocks may have been glaciated *in situ*, and then broken off and pushed along and into the shales.

The tendency of the foregoing facts and phenomena is towards proving that the period of greatest cold preceded the deposition of the Low-level Boulder-clay. This I have already pointed out, first in 1874 and in various papers since.

Discussion.

The President, while admitting that Mr. Reade's evidence seemed to point to land-ice, said that it was difficult to imagine a glacier on so slight a slope as that between the Lake-country hills and Liverpool.

Mr. Whitaker insisted that the lower bed, having no erratics from a distant source in it, must have been of different origin from that with so many far-travelled blocks.

Dr. Hinde said that the absence of far-travelled erratics in the till of the area described by Mr. Reade was a local and not a general characteristic of this kind of rock, since in the lake-region of Canada and the United States the till, which is believed to have been similarly formed by land-ice, contains an abundance of erratics from distant localities, though it is mainly composed of the débris of local rocks.

The Author admitted the difficulty suggested by the President as to the motion of ice from so distant a source as the Lake-district over so slight a slope. He believed, however, that the mechanics of land-ice remained to be explained; but the facts he had recorded in the paper seemed to him quite irreconcilable with the theory that the deposit was formed by floating ice either as icebergs or shore-ice. In reply to Dr. Hinde, he stated that he did not think that the view that the Canadian Boulder-clay was due to land-ice was by any means proved to be the true one.

33. *On an almost perfect* SKELETON *of* RHYTINA GIGAS * (RHYTINA STELLERI †, "STELLER'S SEA-COW"), *obtained by* MR. ROBERT DAMON, F.G.S., *from the* PLEISTOCENE PEAT-DEPOSITS *on* BEHRING'S ISLAND. By HENRY WOODWARD, LL.D., F.R.S., F.G.S., &c. (Read March 25, 1885.)

THE extinction of any group of animals by the influence of man or other agencies cannot fail to be a subject of interest to the palæontologist. Unfortunately the list of exterminated species has now become extremely large, and it seems impossible to doubt that in a few more years all the larger Mammalia not reduced to domestication, or under protective legislation, will have succumbed to man the destroyer.

The musk-sheep, bison, giraffe, African elephant, wild deer, antelopes, and the large-horned wild sheep of the Alpine ranges, are all eagerly stalked down by the modern sportsman; whilst the hunter, in search of ivory, horn, bone, furs, or hides, wages a ruthless war of extermination against them all. The "fur-seal" and the "whale-fisheries" are still pursued; and though the pursuit of the latter is now much diminished, the steady destruction of all the Pinnipedia in both the northern and the southern hemisphere continues with unabated ardour.

I wish, very briefly, to draw your attention this evening to a remarkable animal, now extinct, the *Rhytina gigas* (=*Rhytina Stelleri*), commonly known as "Steller's Sea-cow."

This interesting species of marine phytophagous mammal, once no doubt abundant along the shores of Kamtschatka, the Kurile Islands, and Aliaska peninsula, but now entirely extinct, was first discovered by the eminent German naturalist Steller ‡, who, in company with Vitus Behring, a captain in the Russian Navy and a celebrated navigator of the northern seas, was with his vessel and crew cast away upon Behring's Island (where Behring died), in 1741.

We have fortunately preserved to us Steller's original description of the animal, as seen alive by him, during his long enforced residence on the island; and no other competent observer has since had the same opportunity; for between 1742 and 1782, a period of forty years, this large and harmless mammal appears to have been entirely extirpated, for the sake of its flesh and hide, around both Behring's Island and Copper Island, to the shores of which in Steller's time it was limited.

The bones of the *Rhytina* are not to be seen anywhere lying upon the surface of the ground in either of the two islands, nor do they occur along the shore at the level of the sea, but they are met with at a distance from the shore in old raised beaches and the Post-tertiary peat-mosses, deeply buried and thickly overgrown with

* Zimmermann, 1780. † Desmarest, 1819.

‡ "De Bestiis marinis, auctore Georg. Wilhelm. Stellero" &c. Mém. Acad. Sci. St. Pétersbourg (read 1745 published 1751), tom. ii. pp. 294–330.

luxuriant grass. It would be next to impossible to find them by digging, but they are found by boring into the peat with an iron rod or some such tool. The same method is adopted in the peat-deposits in Ireland, when one desires to find a timber-tree for gate-posts or other purposes; the resistance offered to and the sound emitted by the boring-rod, when in contact with a solid, is at once noticed by the operator. The specimen now in the British Museum was obtained from compact peat, and all the vertebræ and other bones having cavities in them were full of peat-growth when they arrived, as was also the skull. I am informed that in Aliaska territory bones of the *Rhytina* have been obtained in a similar manner from deposits of peat.

A detailed description of the *Rhytina* is rendered almost supererogatory by the magnificent work of the late Dr. J. F. Brandt, of St. Petersburg, who in his monograph, 'Symbolæ Sirenologicæ,' 1846–68, has left us a masterly and detailed account of the anatomy of this interesting genus, accompanied by admirably executed plates. Nevertheless the recent acquisition by Mr. Robert Damon, F.G.S., of a specimen nearly as complete as that in the St. Petersburg Museum, and more so than Nordenskiöld's, seems deserving of a brief notice*.

One of the contemporary writers on *Rhytina* with Brandt, after Steller, was Alexander v. Nordmann, Professor of Zoology in the Imperial University of Helsingfors, in Finland (see Beiträge zur Kenntniss des Knochen-Baues der *Rhytina Stelleri*, von Dr. Alexander v. Nordmann, 4to, Helsingfors, 1861, Acta Soc. Scient. Fennicæ, tom. vii. with 5 plates).

Rhytina: *General Characters.*—The *Rhytina* belongs to the order Sirenia, all the species of which are purely aquatic in their habits and of fish-like form of body, which led to their being formerly confounded with the Cetacea, from which, however, they are widely separated.

The head in the Sirenia is rounded, and of moderate size, never disproportionately large, as in the Whales; the neck is short and scarcely offers any marked constriction between the head and body.

The muzzle is truncated and obtuse, and the nostrils, which are placed above the fore part of the snout, are valvular and distinct. The external ear is absent, or very small; the eyes very small with an imperfect eyelid, but a well-developed nictitating membrane. The form of the body is depressed, fusiform, tapering behind, and without any dorsal fin; the tail is flattened and expanded horizontally, as in the Cetacea.

The fore limbs appear to be remarkably free, and capable of being moved from the shoulder-joint. Thus the living Manatee has been observed to use its fore limbs, "manus," to assist in bringing the food towards the mouth in feeding; and, as the mammary glands are axillary, the females all hold the young, in early life, under their arms †.

* The specimen has now been acquired for the British Museum (Natural History), Cromwell Road, London.

† That the appearance of these grotesque animals, no doubt frequently seen

The pelvis in the Sirenia is exceedingly rudimentary, consisting of a pair of small bones suspended at some distance below the vertebral column. (These have not been observed in *Rhytina*.) There is no trace of any hind limb; but a *rudimentary femur* has been noticed in another extinct form of Sirenian (*Halitherium*).

Rhytina: *The Head.*—The head in *Rhytina* is small in proportion to the long and very thick body. The bones of the skull are massive, but very loosely connected together.

Sir Richard Owen observes that this character of the skull, taken in connexion with the density of the bony skeleton, and the absence of cavities * in the bones themselves, reminds one of the skeleton of the Reptilia (Owen, "On the Dugong," Proc. Zool. Soc. 1838, pp. 28–45).

The nasal bones are quite rudimentary; the maxillary border is narrow and straight; the premaxillary bones, forming the rostral portion of the skull, are long and considerably developed in front, forming the strongly curved border of the nasal opening, and projecting with a downward curve (as in *Halicore*, but less acute), its upper and outer contour being very convex, and the lower and inner palatal surface being concave.

The zygomatic arch is strongly developed and much curved. The occipital portion of the skull is the

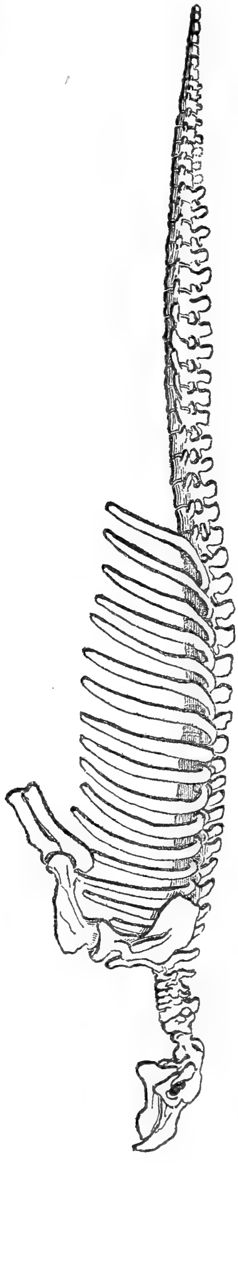


Fig. 1.—*Skeleton of the Extinct* Rhytina gigas, *Linn.*=R. Stelleri, *Desmar.* (Length 19 feet 6 inches.) Behring Island. Original preserved in the British Museum (Natural History).

by the earlier voyagers, both in the East and West Indies and on the coasts of Africa, should have originated the legends of Mermaids and Sirens, seems at first sight incredible; but art was then in its infancy in this country, and doubtless the engraver, who pourtrayed at *second hand* the features of the "sea-siren," had but little assistance in his delineation from the narrator.

* *Ornithopsis Seeleyi*, Hulke, was not then discovered.

broadest; the supraoccipital portion is very rugose, the condyles are semicircular and prominent, and the foramen magnum is very wide.

The Lower Jaw.—The lower jaw is deep in proportion to its length. The coronoid process rises very little above the condyle itself. The symphysis of the mandible extends for about one third (or rather more) of its length, having a convex contour on its upper surface to correspond with the concave contour of the premaxilla. The symphysial surface is very rugose.

Teeth absent or only Rudimentary Incisors.—Two kinds of teeth (molars and incisors) are usually present in most of the Sirenia *. Dr. James Murie, in his elaborate and exhaustive memoir on the Manatee (Trans. Zool. Soc. vol. viii. 1872, pp. 127–202, pl. xvii.–xxvi.), observes: —"Although *Rhytina* was edentulous in the adult condition, I strongly suspect that, like other Sirenian genera, *rudimentary teeth* may have existed in its earlier stages of growth. Nordmann seems also favourably inclined to this opinion."

Trace of Rudimentary Incisors.—It is interesting to observe, in confirmation of Dr. Murie's observation, that the skulls of *Rhytina* in the British Museum demonstrate the former presence of small rudimentary incisor teeth in the premaxillaries, two small alveoli being clearly shown; and the sides of these bones are swollen slightly, just where the pulp-cavities of these small incisors would have been present.

Horny Palate.—As compensation for the absence of teeth in *Rhytina*, the palate and sides of the gums of both the upper and the lower jaw were covered by tough corrugated horny plates, of peculiar structure, which assisted in the process of mastication.

With regard to the structure of the palatal and mandibular laminæ, although their function was undoubtedly that of the trituration of food, Prof. Brandt has shown † that they are destitute of true bony or dental substance, and that they are in fact indurated epithelium.

Dr. Murie has also expressed his conviction that the strongly ridged palatal plate in *Rhytina* is homologous with that found in *Manatus* and *Halicore*. "It certainly," he adds, "does not appear to me to be the representative of teeth, nor of the *baleen* plates met with in the true Cetacea." "The maxillary alveolar ridges are narrow and quite behind the *bruising-plate*, the latter occupying the intermaxillary and not the maxillary bones" (Murie, Trans. Zool. Soc. vol. viii. 1872, p. 167).

Cast of Brain-cavity secured.—Advantage was taken of the loose and readily separable state of the sutures of the skull, to make a careful gelatine mould of the brain-cavity. The result is shown in the cast exhibited, which differs somewhat from the figure (similarly obtained) of the brain-cavity of *Rhytina* taken by Brandt.

Brandt cited on Brain of Rhytina.—That author observes that, according to Steller, *Rhytina* has a small cerebrum, which is not

* In *Prorastomus* canines are also developed; but *Rhytina* possessed neither.

† Brandt, Mém. Imp. Acad. Sci. St. Pétersbourg, 1846, vi. série, pt. ii. Sci. Nat. vol. v. livr. iv. pp. 1–160, tab. i.–v.

separated from the cerebellum by a bony septum: he was unable to find any other peculiarity. He proceeds:—"As no brain was preserved, the only means of knowing its form was by taking casts of the cranial cavity with plaster of Paris. In general character the brain of *Rhytina* is intermediate in form between those of *Halicore* and *Manatus*. In some points perhaps it is nearer to the former, but in others it approaches *Manatus*. The cerebral hemispheres higher and more elongated than in the Manatees; the posterior lobes of the hemispheres longer and higher than the anterior ones, convex above and impressed laterally, and the medulla oblongata projecting above, in the form of a median longitudinal crest; all show a resemblance to the brain of *Halicore*. The hemispheres of *Rhytina* are, on the contrary, shorter than in *Halicore*; the anterior lobes of the hemispheres of *Rhytina* are impressed on their anterior faces and not convex as in *Halicore*; again the medulla oblongata of *Rhytina* is very broad, and the corpora clavata are more depressed from the sides than in *Halicore*, and remind one rather of *Manatus*. But besides the above-mentioned affinities to *Halicore* and *Manatus*, *Rhytina* also shows peculiar characters of its own.

"Thus the anterior lobes of the hemispheres of *Halicore* are exceedingly convex; in *Rhytina* they are even more so, and even higher than in the Manatee; they are depressed from the same cause, on the anterior surface, especially on the sides, but less than in *Halicore* and *Manatus*, but they overhang in the middle to a greater degree. The posterior lobes of the hemisphere of *Rhytina*, on their posterior border with the cerebellum, are broader than in the other genera of Sirenians before mentioned (and in this respect they are not unlike the same lobes in the elephant); they also show on the upper surface an oval convexity or furrow; these then constitute peculiarities. The hemispheres of the brain of *Rhytina* further differ in this, that they appear to approximate very closely to one another. The cerebellum in *Rhytina* is depressed to a greater extent, and is broader and stronger than in the other genera. The brain in *Rhytina* affords therefore a form intermediate between *Halicore* and *Manatus*. Otherwise the brain of the *Rhytina*, considering the huge size of the body of the animal, seems to be six times smaller * in proportion than that of *Manatus* or *Halicore*. The plaster-cast of the brain of *Rhytina* shows traces of the small optic nerves, and of a very large fifth hypophysis showing a rounded prominence"†.

Bones of the Ear of Rhytina Stelleri *preserved*.—The os petrosum of the periotic, with the tympanic annulus, is preserved on both the right and left sides of the skull.

On removing the peat from the cavity of the mid-ear Mr. C.

* This agrees with Prof. Marsh's observations on the smallness of the brain in Tertiary mammals, and is in favour of the very high antiquity of *Rhytina*. See Marsh in Silliman's Journ., "On the small size of Brain in the Tertiary Mammalia," 3rd series, vol. viii. 1874, p. 66, ibid. op. cit. vol. xii. 1876, p. 61 and vol. xxix. 1885, pp. 190–193.

† Brandt, "Symbolæ Sirenologicæ," fasc. iii. 1878, p. 256. Tab. ix. Mém. de l'Acad. Imp. d. Sc. St. Pétersbourg, sér. vii. tom. xii.

Barlow (the *formatore* of the Geological department) discovered the three auditory ossicles still within the cavity. They agree very closely with the figures given by Brandt *, and are also near to the ossiculæ auditus of the Manatee.

The Stapes.—The stapes is a short columella-like bone, flattened at each end, having a small perforation (which may perhaps indicate the remnant of a much larger opening, the stirrup, observable in this bone in some other mammalia). It fits at one end into the fenestra ovalis, and unites at the other with the end of the incus.

The Incus.—The incus is longer and stouter, and the superior and inferior faces are depressed, and the posterior process, the long *crus*, which articulates with the *stapes*, is shorter than in the Manatee and Dugong.

The Malleus.—The body of the malleus is much swollen, more so than in the Dugong; the superior face is convex, not depressed, as in *Manatus latirostris*. The external process of the malleus has a straight internal border (not arched as in *Manatus*); the external border is strongly arched (not truncated below); the external face is greater in breadth and is flatter than in *Manatus*. The condyles, articulating with the incus, are bilobed and depressed.

Bones of the Scapular Arch and Fore Limb.—The sternum has been figured by Brandt †. It is a much stouter and stronger bone than in the Manatee, but is similar in form.

Scapula.—The scapula is somewhat convex externally, the inner concave face fitting closely against the anterior ribs to which it was applied; the spinous process of the scapula is strongly developed. The glenoid cavity is deep and circular and well fitted to the rounded head of the humerus; the humerus is short and stout; the radius and ulna, which are also short, are anchylosed together at both extremities and incapable of any rotatory motion; the olecranon is strongly produced and curved, showing that the fore arm as well as the humerus had considerable free lateral movement for the act of swimming.

The Manus.—The carpal bones and digits are unknown in *Rhytina*; the digits were probably five, as in *Manatus* and *Halicore* (but the thumb in the latter is rudimentary). Externally viewed the fore limbs in *Rhytina* were fin-like, with no external digits or nails visible; but Steller describes their extremities as thickly covered with short bristly hairs.

Density of Skeleton.—The skeleton is remarkable for the massiveness of the bones, especially the great density of the ribs, which have the hardness of ivory. There is a general absence of medullary cavities in the bones.

The great specific gravity of the bones no doubt assisted these

* See also Claudius "On the organs of hearing in *Rhytina*," Mém. Acad. Imp. Sci. St. Pétersbourg, 1867, vol. xi. no. 5, 2 plates; Brandt, "Symb. Siren." Fasc. ii. pp. 8–10, Tab. ii. figs. 11–20. Mém. Acad. Imp. Sci. St. Pétersbourg, sér. vii. 1861.

† I believed we also had in the Museum an imperfect sternum of *Rhytina*, and Prof. Flower, after comparison, agrees in this determination.

animals in keeping their large bodies sunk beneath the surface of the shallow waters in which they dwelt whilst feeding upon the marine vegetation upon which they wholly subsisted.

Variations to the rule of seven Cervical Vertebræ usually obtaining in the Mammalia.—Although the normal number of cervical vertebræ maintained in the Mammalia is usually seven, yet some of the Sirenia (such as the "American Manatee") have only *six*. Conversely in *Bradypus* the number of the cervical vertebræ is increased to *eight or nine*. This is explained by the fact that the thoracic vertebræ in *Bradypus* pass into the cervical region, while the diminution to six in *Cholœpus* and in the American Manatee is similarly explained by the complete development of the rib of the seventh cervical vertebra.

Rhytina has been described by Steller as only possessing six cervical vertebræ, like the Manatee; but Brandt correctly gives the number as seven, and the specimen now in the Museum confirms this determination.

The atlas- and axis-vertebræ in *Rhytina* are fairly robust, and the atlas is as broad as the second dorsal vertebra; but the five remaining cervical vertebræ, although quite free, are thin and plate-like, as in the Cetacea proper. But the Sirenia are distinguished from the true Whales by their capability of moving the head from side to side, and up and down, by means of the "odontoid" process of the axis vertebra on which the head rotates. In the Cetacea, in which the cervical vertebræ are anchylosed together to a greater or less extent, and the neck is consequently immovable, the odontoid process is also wanting.

As the Sirenia spend their whole lives browsing upon the *Laminariæ* and other Algæ and aquatic plants, this power to move the short neck pretty freely must be essential to them both in feeding and also in putting up their heads to breathe.

The number of vertebræ attributed to the Sirenia, both of living and extinct genera, is very variable according to different authors. Prof. Brandt attributed to *Rhytina* 7 cervicals, 19 thoracic or dorsal vertebræ, and from 34 to 37 lumbar, sacral, and caudal. The cervicals and dorsals are readily determined; but, as none of the vertebræ are anchylosed together to form a sacrum, it is a matter of some difficulty to decide which are lumbar and which are sacral vertebræ.

Not only does anchylosis never occur in the vertebræ of the Sirenia, but the flat ends of the centra of the vertebræ *do not ossify separately* so as to form disk-like epiphyses in the young state, as is commonly the case in all the other Mammalia.

Brandt indicates the 7th vertebra beyond the last of the dorsal or thoracic series as bearing the rudimentary pelvis; but as the vertebræ are never *anchylosed* to form a sacrum, we can only conjecture (by noticing a slight prominence upon the posterior border of the extremely wide transverse processes) which of these lumbar-sacral vertebræ seem marked as sacral, probably about the 5th, 6th, and 7th. The 13 vertebræ next behind the dorsal series may, from their

size and their wider and longer transverse processes, be considered lumbar and sacral, and the 21 following vertebræ as caudal; about 6 or 8 of the most anterior of the latter had small chevron-bones or hæmal arches attached to them in the St. Petersburg specimen.

The transverse processes in the caudal series are much smaller, thicker, and shorter, and are directed obliquely backwards.

Variation in form of the Centra in the Vertebral Column.—There is a marked change in the form and size of the neural arch and the centrum of the several vertebræ in the spinal column, from before backwards. The anterior dorsal vertebræ have each a small compressed centrum, much broader than deep; the neural arch is triangular, the neural spine erect.

From the 5th to the 8th dorsal the centra are longer and cordiform, and the neural canal is smaller and more rounded; the neural spine bends backwards, and the zygapophyses are more prominent.

The lumbar vertebræ are much dilated laterally, the centra being nearly three times as broad as deep. The neural canal is reduced in size, and the neural spine is moderately large; but the transverse processes are very flat, long, broad and straight, being in relation to the centrum as 5 to 1.

The centra of the caudal vertebræ are rounder, the transverse processes are short and stout and bent backwards; the neural canal is reduced to a very small size, and the neural spine gradually disappears.

The earlier caudals have short V-shaped chevron-bones or hæmal arches.

The 11th to 16th thoracic or dorsal vertebræ have irregularly developed hypapophyses on the ventral surface of their centra.

There are 19 pairs of ribs in *Rhytina*, probably not more than two pairs of which were articulated to the sternum. The 1st and 2nd pairs are short and much compressed laterally, the third and following are round and very massive, and increase in curvature and length up to the 12th, when they gradually become shorter and less curved, the 19th being quite rudimentary.

This large number of rib-bearing vertebræ in the Sirenia is only equalled in *Elephas* and *Rhinoceros*, and only exceeded in *Dendrohyrax* (which has 22 costal vertebræ), thus affording another point of analogy in *Rhytina* to the Ungulata*.

The ovoid visceral cavity thus enclosed within the bony walls of the ribs is of vast dimensions; and one realizes readily the statement that a full-grown male, covered with its integument and flesh, weighed as much as $3\frac{1}{2}$ tons.

Habits of Rhytina, &c.—The Sirenia pass their whole life in the water, being denizens of the shallow bays, estuaries, lagoons, and

* The teeth in *Manatus* and *Halitherium* approach in form to the molars in *Hippopotamus*, *Mastodon*, and the Suidæ.

Dr. Murie strongly insists upon the dermal characters as offering a very close resemblance between *Manatus* and *Elephas*. The short (rudimentary) nasal bones and the prolonged premaxillaries, with their tusk-like incisors, afford further points of resemblance with the Proboscidea.

large rivers; but they never venture far away from the shore. Their food consists entirely of aquatic plants, upon which they browse beneath the surface, as the terrestrial herbivorous mammals feed upon the green pastures on land*.

When Steller came to Behring's Island in 1741, the Sea-cows pastured in the shallows along the shore, and collected in herds like cattle. As they fed, they raised their heads every four or five minutes from below water in order to breathe before again descending to browse on the thick beds of sea-weed which surround the coast.

They were observed by him to be gregarious in their habits, slow and inactive in their movements, and very mild and inoffensive in their disposition. Their colour was dark-brown, sometimes varied with spots. The skin was naked, but covered with a very thick, hard, rugged, bark-like epidermis, infested by numerous parasites.

When full-grown they are said to have sometimes attained a length of 35 feet and a weight of 3 or 4 tons.

Like most of the Herbivora, they spent the chief part of their time in browsing. They were not easily disturbed whilst so occupied, even by the presence of man. They entertained great attachment for each other; and when one was harpooned, the others made incredible attempts to rescue it. They were so heavy and large that, Steller records, they required 40 men with ropes to drag the body of one to land.

Fossil and Recent Allies of Rhytina.—In Miocene and Pliocene times Sirenians were abundant over a large portion of Europe. Many of these are referable to the genus *Halitherium*, first described by Kaup from the Miocene of Hesse Darmstadt.

Halitherium resembled the Dugong in its dentition (fig. 3), having tusk-like incisors in the upper jaw, though these were not so largely developed as in *Halicore*. The molar teeth were $\frac{5}{5}$ or $\frac{6}{6}$, the anterior teeth were simple and single-rooted, the posterior teeth of the upper jaw with three roots, and those below with two roots, and with enamelled and tuberculated or ridged crowns, in all which points they resemble the Manatee more than the Dugong. The anterior molars were deciduous.

The pelvic bones are better developed than in existing Sirenians (fig. 2); there is also a rudimentary styliform femur. They were therefore less specialized than their modern representatives (Flower).

In *Prorastomus* (Owen) from the Tertiary of Jamaica, the dentition is very remarkable; for we have present at one and the same time, clearly differentiated—incisors $\frac{3-3}{3-3}$, canines $\frac{1-1}{1-1}$, premolars $\frac{5-5}{5-5}$, and molars $\frac{3-3}{3-3}=48$ teeth.

* Mr. William Carruthers, F.R.S., F.G.S., informs me that the large sea-weeds called *Laminariæ* grow in water at or just below low-water; they are nutritious and are eaten by animals. They abound in the North Pacific Ocean. Ruprecht, in his account of the Algæ of the North Pacific, records eight species of these large weeds growing in the Sea of Ochotsk, on the shores of Kamtschatka, and the north of North America. He adds:—"When I went to see the Coniferous trees at Monterey, California, last autumn, I was surprised at the magnitude and quantity of the *Fuci* and *Laminariæ* thrown up on the coast."

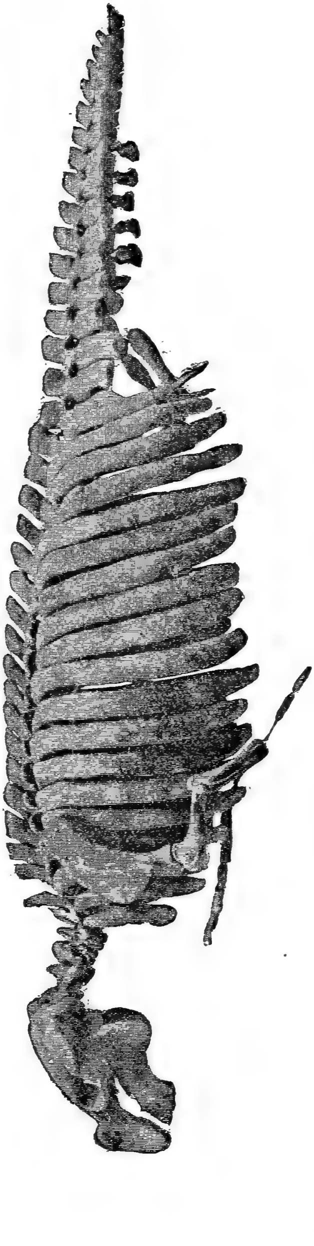
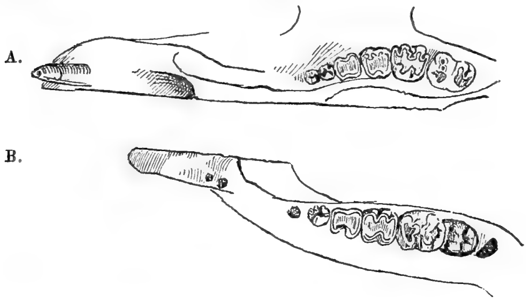


Fig. 2.—*Skeleton of* Halitherium Schinzi, *Kaup**, *Miocene*, *Darmstadt*. (After the restored skeleton in the Museum at Darmstadt.) Photographed from the cast of the specimen from the Darmstadt Museum, prepared by Prof. Dr. G. R. Lepsius. Now in the British Museum (Natural History), Cromwell Road. Length 7 feet 8 inches.

* See Memoir on *Halitherium Schinzi*, die fossile Sirene des Mainzer Beckens, von Dr. G. R. Lepsius: Darmstadt, 1881 (Abh. des Mittelrhein. geolog. Vereins, I. Band, Lief. I. pp. 70); and ten quarto plates.

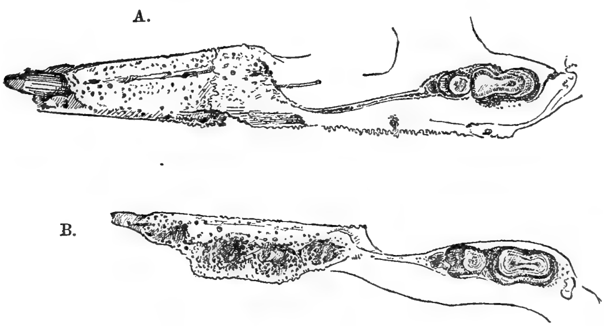
Halicore (fig. 4), at first sight, seems widely separated, and appears to approach towards the condition of *Rhytina*, having in the adult

Fig. 3.—*Dentition of* Halitherium Schinzi, *Kaup.*



A. Left half of the palate. B. Part of left ramus of mandible.

Fig. 4.—*Dentition of* Halicore australis. *Queensland.*



A. Left half of the palate. B. Part of left ramus of mandible.

state only one pair of incisors left in the upper jaw, and two (rarely three) molars on each side above and below, making 14 teeth in all.

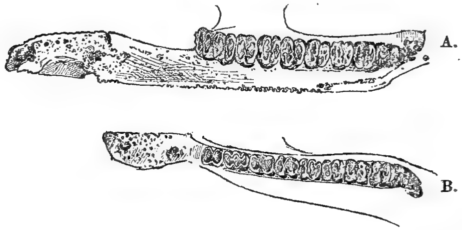
But, adding the milk-dentition, we have

	Incisors.	Molars.
Milk-dentition	$\frac{1-1}{3\ \ 3}$	$\frac{3-3}{3-3}$
Permanent teeth	$\frac{1\ \ 1}{0-0}$	$\frac{2-2}{2-2}$ rarely $\frac{3-3}{3\ \ 3}$

The teeth in *Halicore* are more or less cylindrical; the incisors in their form and wear resemble those of the Hippopotamus. The last molar is compressed laterally, giving the crown a figure-of-eight shape; but there is no distinction into root and crown. The summits of the crown are tuberculated before wearing; afterwards they are flattened or slightly concave.

In *Manatus senegalensis* (fig. 5) there are milk-incisors present $\frac{1-1}{1-1}$, which disappear. The molars amount to $\frac{11-11}{11-11}$; the upper molars have two ridges and three roots; the lower mandibular series have an additional posterior ridge or talon, and only two fangs.

Fig. 5.—*Dentition of* Manatus senegalensis. *West Coast of Africa.*



A. Left half of the palate.
B. Part of left ramus of mandible.

The teeth drop out in front, and are renewed from behind as in the Proboscidea.

This extreme variation in the number of the teeth from 2 to 48 is exactly paralleled in the Cetacea, in which we have many edentulous species (Balænidæ); others with only two teeth present (Ziphioid Whales); others again with very numerous teeth (Delphinidæ).

All the earlier voyagers confounded the Sirenia with the Seals, and the *Rhytina* with the Morse or Walrus.

In 1811, Illiger separated the three genera—*Manatus*, *Halicore*, and *Rhytina*, under the name Sirenia, and placed them between the Seals and the Cetacea. They are now placed by Prof. Flower and other naturalists between the Ungulata and the Cetacea.

The following is a List, with their distribution, of the *existing species* of the order Sirenia:—

Manatus senegalensis, Desmarest (the African Manatee), inhabiting the west coast of Africa from about 16° N. to 10° S. lat. and as far into the interior as Lake Tchad; and according to native accounts, to the River Keebaly, 27° E. long.

Manatus latirostris, Harlan (the West Indian Manatee), inhabiting the creeks, lagoons, and estuaries of the West Indian Islands and coast of Florida.

Manatus americanus (the Brazilian Manatee), inhabiting the coast as far south as about 20° S. lat., and the great rivers of Brazil almost as high as their sources.

Halicore tabernaculi (the Dugong) inhabiting the Red Sea and the east coast of Africa.

Halicore dugong, inhabiting the Indian Sea, Ceylon, Bay of Bengal, Indo-Malayan Archipelago, and Philippine Islands.

Halicore australis, the coasts of Eastern and North Australia.

Passing to the West Indies, we find a fossil species from thence having important differences in dentition, by which to separate it from the now living *Manati.* Three other species occur in the Tertiary beds of South Carolina; and a doubtful form in the deposits of Darling Downs, Queensland, Australia.

Lastly, there is the extinct *Rhytina* of Behring's Island now under notice. We have, then, at the present day living in America, Africa, India, and N.E. Australia, two genera and six species of Sirenia; and in Europe, Africa, and America, 12 genera and 27 species of extinct Sirenians.

Conclusion.—Distribution of the Sirenia.—There are, it appears to me, two very important points in connexion with the Sirenia which are worthy of our special attention as geologists and palæontologists.

I allude to the present and the past distribution of this order over the world.

If we take the belt of the tropics, that is $23\frac{1}{2}°$ N. and $23\frac{1}{2}°$ S. of the equator (or, better still, say 30° N. and S. of the equator), *we shall cover the geographical distribution of all the living Sirenians.*

If we take another belt of 30° *North beyond the tropic of Cancer*, we shall embrace *the whole geographical area in which fossil remains of Sirenians have been met with.*

Assuming, as I think we may, that the Sirenia at the present day *belong exclusively to the tropical regions of the earth*, and that *Rhytina*, in its boreal home, was simply a surviving relic from the past (a sort of geological "*outlier*," as of a stratum elsewhere entirely denuded away), we must conclude that the presence of about 12 genera and 27 species of fossil Sirenia, as widely distributed then as the recent forms are at the present day, *but with a range from the tropic of Cancer up to* 60° *of north latitude*, affords a most valuable piece of evidence (if such were needed), attesting the former northern extension of subtropical conditions of climate which must have prevailed over Europe, Asia, and N. America, in Eocene and Miocene times and in the older Pliocene also.

The early appearance of so highly modified a form of mammal, its abundance, distribution, and variations, serve to attest the great lapse of time occupied in the accumulation of even our later Tertiary deposits, which we are sometimes apt to pass over as representing but a very brief chapter in the geological history of our earth; and further, it must necessitate our carrying back the *Mammalian class far into Secondary times.*

Note.—Drifted remains of Manatee (either from Florida or from the West Indies) are recorded as having reached our shores, probably on the waters of the "gulf-stream," in 1785.

The carcass of one of these animals was washed ashore at Leith; it was much disfigured, but Mr. Stewart informed Dr. Fleming that it was the putrid body of a Manatee, or *Manatus borealis.* (Bell, Brit. Quadrupeds, 8vo, 1837, p. 525.)

The following is a list of fossil Sirenia, with formations and localities:—

Chirotherium subapenninum, Bruno. Pliocene: Piedmont. Mem. Acad. Sci. Tor. ser. ii. vol. i. (1839) p. 143.

Chronozoon australe, C. W. de Vis, Proc. Linn. Soc. N. S. Wales, 1883, viii. p. 382, pl. xvii. Pliocene: Darling Downs, N. S. Wales.

Crassitherium robustum, Van Beneden. Pliocene: Belgium.

Diplotherium Manigaulti, Cope. Miocene?: S. Carolina; Proc. Acad. Philad. 1883, p. 52.

Eotherium ægyptiacum, Owen. Eocene?: Mokattam, Cairo; Quart. Journ. Geol. Soc. vol. xxxi. p. 100.

Felsinotherium Forestii, Capellini, 1872. Pliocene: Riosto, Bologna; Mem. dell' Acad. delle Sci. dell' Istit. di Bologna, ser. iii. tom. i. fasc. 4, pp. 605–634, tav. i.–vii.

—— *Gervaisii*, Capellini, 1872. Pliocene: Siena, *op. cit.* pp. 634–642, tav. viii. (*Felsinotherium* closely resembles *Halicore*:—i. $\frac{1\ \ 1}{}$ m. $\frac{5}{5}\ \frac{5}{5}$.)

Halitherium Serresii, Gervais. Pliocene: Montpellier; d'Estrés (Bouches-du-Rhône); Gervais, Zoologie et Paléontologie Françaises, 2nd edit. Paris, 1859, p. 277.

—— *fossile*, Cuv. sp. Miocene: St. Maure, Loire; Angers, Rennes, Morbihan; Gervais, *op. cit.* p. 281.

—— *Beaumontii*, Christol, sp. Miocene: Beaucaire, Gard, Gervais, *op. cit.* p. 281.

—— *Guettardii*, de Blainv. Miocene?: Etréchy (Seine), &c. &c. Gervais, *op. cit.* pp. 281, 282.

—— sp.

—— *dubium*, Cuv. Eocene: Blaye, Gironde, Gervais, *op. cit.* pp. 281, 282.

—— *bellunense*, Zigno, 1875, Mem. del Reg. Ist. Veneto, vol. xviii. part iii. 1875, pp. 438–444, tav. xiv. figs. 1–5, tav. xv. figs. 1–7. Miocene: Belluno, Venetia.

—— *angustifrons*, Zigno, 1875. Miocene: Belluno, *op. et loc. cit.* pp. 441–443, tav. xvi. figs. 1–4.

—— *curvidens*, Zigno, 1875. Miocene: Belluno, *op. et loc. cit.* pp. 443–445. tav. xvii. figs. 1–4.

—— *veronense*, Zigno, 1875. Miocene: Belluno, *op. et loc. cit.* pp. 445–449, tav. xviii. figs. 1–10.

—— *Schinzi*, Kaup, Beiträge zur näheren Kenntniss der urweltl. Säugeth. 1855. Miocene: Darmstadt; Miocene: Malta.

—— *Canhami*, Flower. Crag (derivative); Quart. Journ. Geol. Soc. vol. xxx. pp. 1–7.

—— *Cuvieri*, Owen. Miocene: Montpellier.

—— sp., Van Beneden. Miocene ("Bolderian"): Elsloo, near Maestricht.

—— (*Chirotherium*) *Brocchii*, Bruno (Owen, *cit.*). Miocene: Herault.

——, sp., Zigno, Mem. Ist. Venet. vol. xviii. 1875, pp. 427–453. Miocene: Chalaif, Isthmus of Suez.

Hemicaulodon effodiens, Cope. Eocene: Shark River.

Manatus Coulombi, Filhol (1878) (named after M. Coulomb, the discoverer). From the Eocene? Quarries, Mokattam, near Cairo (founded on three teeth of lower jaw like the Manatee); Bull. Soc. Philom. de Paris, 7e sér. tom. ii. pp. 124, 125.

—— *inornatus*, Leidy. Miocene?: Phosphate beds, South Carolina; Rep. U.S. Geol. Survey, i. p. 336.

Pachyacanthus trachyspondylus, Brandt (in part), Van Beneden, *emend.*, 1875. Miocene: Nussdorf, near Vienna; Bull. Acad. Roy. Soc. 2nd ser. t. xl. 1875, pp. 323–340. (Based on vertebræ and ribs of a Sirenian,) Zool. Record vol. xii. 1875, p. 14.

Prorastomus sirenoides, Owen. Tertiary: Jamaica; Quart. Journ. Geol. Soc. 1855, vol. xi. pl. xv. figs. 1–6, vol. xxxi. pp. 559–567.

Rhytina gigas, Zimmermann, Geograph. Gesellsch. 1780. Pleistocene: Behring's Island, =*Rhytina Stelleri*, Desmarest, 1819.

Rhytiodus Capgrandi, Lartet. Pliocene: Basin of the Garonne.

Trachytherium Raulini, Gervais. Miocene: La Réole, Gironde, *op. cit.* pp. 282, 283.

We thus see that remains of Sirenians are met with over the greater part of Europe (in England, Holland, Belgium, France, Germany, Austria, Italy), and in the deposits of analogous age in the Isthmus of Suez at Chalaif, and the quarries of Mokattam near Cairo, in Africa.

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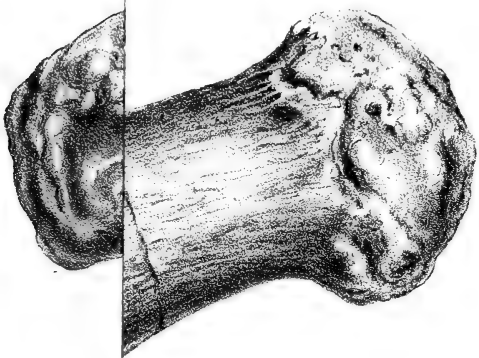
Discussion.

Prof. Boyd Dawkins thought the evidence brought forward supported the view that we are still living in the Tertiary period. He thought *Halicore* was as highly specialized as *Prorastomus*. He believed the multiplication of teeth was connected with the aquatic habit.

Dr. Murie pointed out that the characteristics of the whole group of the Sirenia allied them to the Cetaceans, Pachyderms, and possibly the Ungulates. He insisted on the similarity of the skin of the Sirenia to that of the Elephants. The heart, blood-vessels, bones, muscles, and viscera of the Sirenia are all peculiar. He referred to the differences of the tail in different genera of Sirenia. He did not agree with the enumeration of recent and fossil species, as shown in the diagram. He thought that there might be two, but possibly only one, living species of *Manatus*, and one of *Halicore*, while many of the so-called species of *Halitherium* would not stand.

The Author, in reply to Prof. Boyd Dawkins, pointed out that the presence of canines and differentiated molars and premolars indicated *Prorastomus* to be a more highly specialized form. That the multiplication of teeth in aquatic forms is not a universal rule is shown by the edentulous *Rhytina*.



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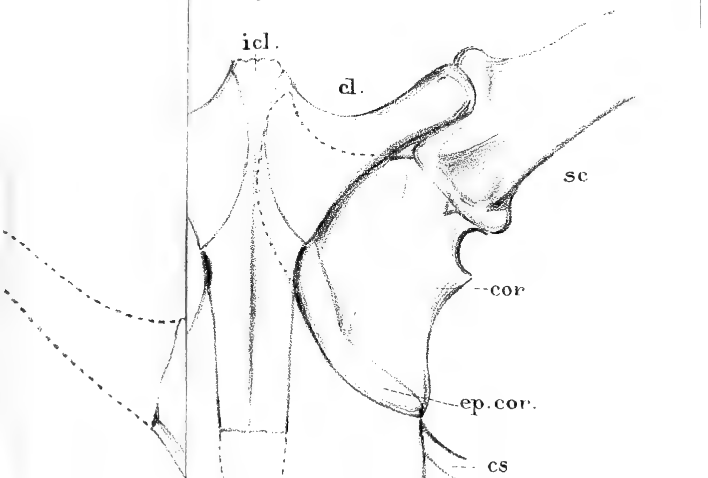

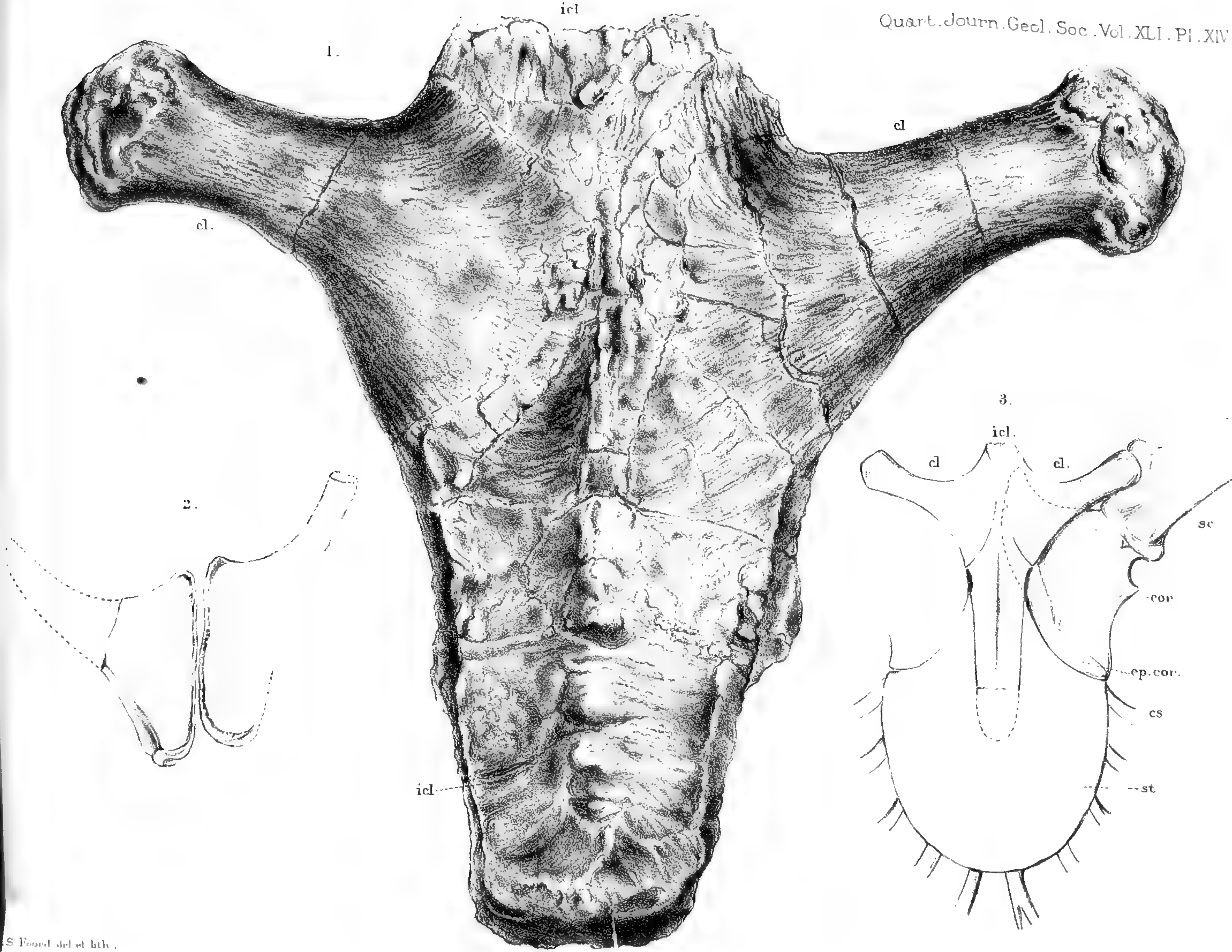

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STERNAL APPARATUS OF IGUANODON.

Mintern Bros. imp.

34. *Note on the* Sternal Apparatus *in* Iguanodon.

By J. W. Hulke, Esq., F.R.S., F.G.S. (Read June 10, 1885.)

[Plate XIV.]

One of the few parts in the osteology of *Iguanodon* upon which the rich series of Bernissart fossils preserved in the Musée d'Histoire Naturelle at Brussels, so ably worked out by M. Dollo, and concerning which the numerous remains discovered in our own country have hitherto not afforded any certain information, is the sternal apparatus*.

A specimen which I lately had the pleasure of seeing in the rich collection of *Iguanodon*-remains made from the Wealden Beds at Hastings by S. H. Beckles, Esq., F.R.S., a Fellow of this Society, appeared to me to supply the desired knowledge. Mr. Beckles readily acceded to my wish to bring it under the Society's notice; and I tender him my warm thanks for his permission, and also for most courteously placing this and other fossils at my disposal for examination and study.

The piece which I identify as part of the sternal apparatus is an azygos bar, from near one end of which two lesser rods diverge laterally, one from each side (Pl. XIV. fig. 1). Each of these rods (*cl*) has an expanded mesial end, a contracted cylindroid shaft, and a swollen outer extremity. The expanded mesial ends are applied to that surface of the azygos bar which I regard as ventral, approaching each other here so closely as to leave between them only a very narrow interval in which the bar is visible. Their dimensions are as follows, viz.:—

Length	22·5 cm.
Breadth of mesial end	16·5 ,,
,, shaft at its middle	5·0 ,,
Longer diameter of outer end	7·5 ,,
Extreme distance between outer ends	46·5 ,,

The identification of these divergent rods with the bone cemented by rock to an *Iguanodon* scapula in the British Museum (recognized first as clavicle by Mr. W. Davies), and also with the two bones figured by M. Dollo as the right and left moieties of the sternum (Pl. XIV. fig. 2), will not, I think, be questioned. Some minor

* Other parts of the pectoral arch—the scapula and coracoid—have long been known, the clavicle more recently. The latter was first, I think, recognized as such by Mr. W. Davies. His identification was accepted by Prof. O. C. Marsh, and subsequently by myself, with some reservation (Quart. Journ. Geol. Soc. vol. xxxix. p. 61).

differences are, I think, fairly attributable to mutilation and compression. The symmetry of their junction with the azygos bar strongly favours the belief that we see here preserved the undisturbed normal relation of the several parts. On this supposition the two divergent rods occupy precisely the position, and they have the same relation to the azygos bar or interclavicle (Pl. XIV. fig. 3, *icl*) as the clavicles in extant Lacertilia; for the apposition of their outer ends to the process termed "acromial" on the anterior border of the scapula will hardly be doubted.

The azygos piece (Pl. XIV. fig. 1, *icl*) has the form of a long flattened bar, the width of which appears to increase slightly from that which I regard as its anterior end to a point about 9·5 c.m. behind the clavicles, and thence to decrease slightly to the posterior extremity. The anterior extremity, which advances slightly in front of the mesial ends of the clavicles, is indented at its middle. The posterior margin is nearly straight, but I do not feel certain that this is a natural edge, and that the bar may not originally have been somewhat longer. The lateral borders for the space of 7 c.m. behind the clavicles to the point where the bar attains its greatest width are smooth and arcuate, suggestive of having formed a small segment of a long curved articular groove for the reception of an epicoracoid; whilst the remainder of the border behind this is rough, uneven, and apparently non-articular. A mesial ridge or low keel divides the bar longitudinally. Its greatest elevation is about 1·5 c.m.

Measurements of Azygos Bar.

Length	39·4 c.m.
Width at anterior extremity	11·0 ,,
Maximum width, behind clavicles	15·3 ,,
Length of exposed arcuate part of lateral margin about	7·0 ,,
Width at posterior end of bar	10·0 ,,

What is this azygos bar? That it comprises the interclavicle (*Parker*) (=episternum of some authors, the clavicular sternum, *Hoffmann*), is, I submit, demonstrated by its connexion with the clavicles, which, as I have already said, agrees with that obtaining in existing Lacertilia. But does it comprise the sternum (costal sternum, *Hoffmann*) also? Marks of connexion of costæ with its lateral borders would be decisive of this, but none are recognizable. The extent of the arcuate part of the lateral border is quite incommensurate with the size of the arc which we know the mesial border of the epicoracoid must have had. Lastly, the figure of the azygos bar is quite unlike the shield-like sternum of extant Lacertilia and Crocodilia.

These considerations weigh with me in regarding the azygos bar as an interclavicle only—the homologue of that of now living Lizards, and of the bony sternum, so called, of extant Crocodiles. If this view is correct, the bar was splinted to a shield-like sternum

bearing ribs. The non-recovery of such a sternum by Mr. Beckles, when we bear in mind that under his personal superintendence a very considerable part of the skeleton, including both fore limbs, was exhumed, favours the suggestion that I threw out in my Presidential Address in 1882, that the sternum in *Iguanodon* may have been cartilaginous, as in living Crocodiles.

EXPLANATION OF PLATE XIV.

Fig. 1. The clavicles with the interclavicle. Half natural size. In Mr. Beckles's collection.
2. The bones suggested by Dollo as the moieties of the sternum.
3. Schema of the restored pectoral arch.

The following lettering applies to all the figures:—*cl*, clavicle; *icl*, interclavicle; *cor*, coracoid; *ep. cor*, epicoracoid; *sc*, scapula; *cs*, costæ; *st*, (cartilaginous?) sternum.

DISCUSSION.

The PRESIDENT congratulated the Author on the interesting discovery he had made in connexion with the anatomy of the Dinosaurs.

35. *The* Lower Palæozoic Rocks *of the* Neighbourhood *of* Haverfordwest.

By J. E. Marr, Esq., M.A., F.G.S., Fellow of St. John's College, Cambridge, and T. Roberts, Esq., B.A., F.G.S., St. John's College, Cambridge. (Read June 10, 1885.)

[Plate XV.]

§ 1. *Introductory.*

The country around Haverfordwest is of great interest to geologists, first, on account of the evidence furnished therein of the relations of the graptolite-bearing beds to the strata which are characterized by the presence of higher organisms, and secondly, from the nature of the foldings which the rocks of the district have undergone.

We propose, in this communication, to devote our attention to the former of these subjects.

Our work is based upon that which has been done by the Geological Survey, and published in Sheet 40, Horizontal Sections, Nos. 1 & 2, and Mem. Geol. Survey, vol. ii. part i.

Whilst fully acknowledging the great value of these publications, we think it desirable, now that our knowledge of the forms of life occurring in these rocks has been so much increased by the labours of many geologists in recent years, to attempt a more minute classification of the rocks of this district than that adopted by the Government Surveyors. In our opinion, this further description of the beds will throw considerable light upon the character of the movements which the district has undergone.

Our thanks are due to Dr. Hicks for the very kind way in which he placed a series of specimens collected by himself at our disposal. We have also to thank Prof. Lapworth for his kindness in examining our collection of graptolites.

The area which we have chiefly examined is a well-defined tract (see Map, Pl. XV. fig. 1), about eighteen miles in length from east to west, and having an average breadth of five miles, lying to the north of the towns of Haverfordwest and Narberth. It is bounded on the north by a great fault, running from Roch Castle in an easterly direction, along the margin of a mass of rock which Dr. Hicks has claimed as Pre-Cambrian. On the west and south, the Lower Palæozoic rocks of this tract are succeeded by Old Red Sandstone and Carboniferous deposits, and on the east, a considerable extent of Llandeilo limestone is represented on the Geological Survey map.

Within this area is a portion of a wide synclinal, complicated by minor foldings, running from near Clynderwen Station on the east, to the Coal-measures on the west. South of this is a complicated anticlinal in the neighbourhood of Narberth.

§ 2. *Establishment of the Succession.*

1. *Lingula Flags.*—To the north of the great fault alluded to as

Fig. 1. Geological Sketch-Map, of the Neighbourhood of Haverfordwest.
Scale ½ Inch = 1 Mile.

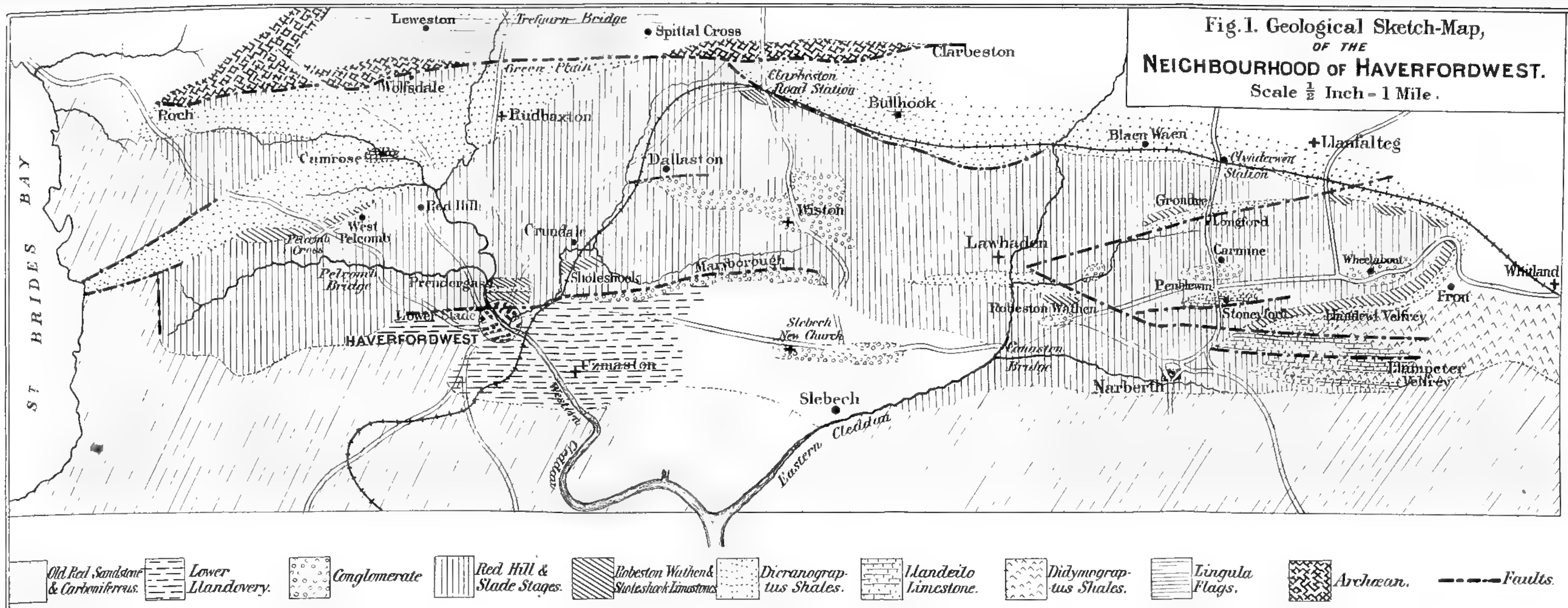
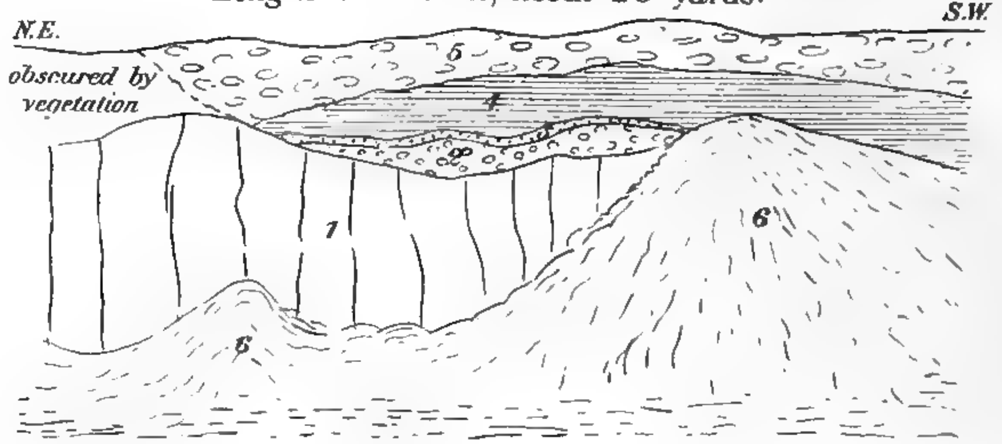


Fig. 2.

Quarry S. E. of Trefgarn Bridge.

Length of Section, about 20 yards.

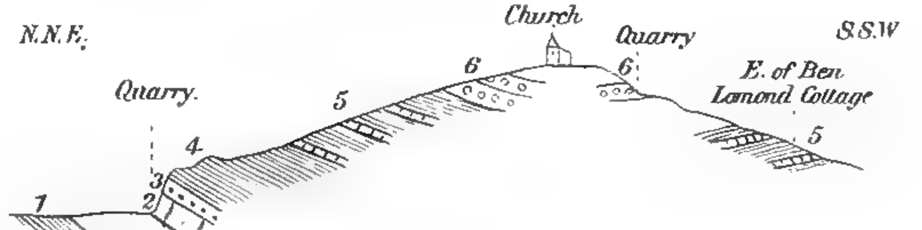


1. *Archæan, about 18 ft. seen.*
2. *Conglomerate.*
3. *Grit.*
4. *Shales with Olenus &c.*
5. *Drift.*
6. *Debris.*

Fig. 3.

Section through Robeston Wathen.

Length of Section, ¾ mile.

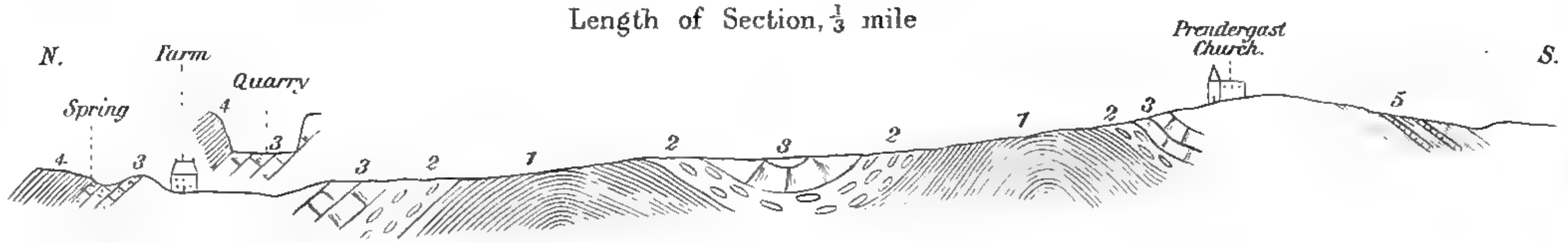


1. *Dicranograptus Shales.*
2. *Robeston Wathen Limestone.*
3. *Summit of Sholeshook Limestone Stage.*
4. *Red Hill Stage.*
5. *Slade Stage.*
6. *Conglomerate.*

Fig. 4.

Section in Lane N. of Prendergast Church.

Length of Section, ⅓ mile

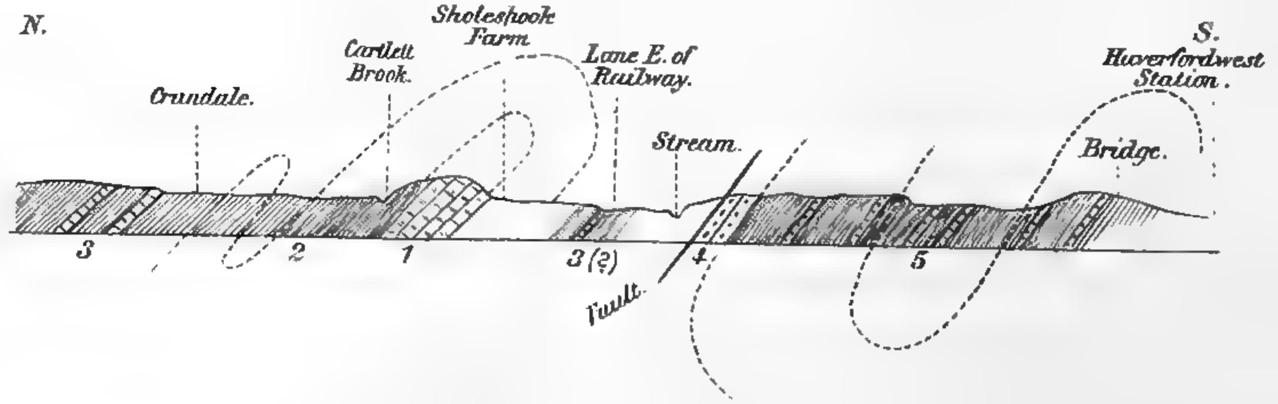


1. *Dicranograptus Shales.*
2. *Calcareous summit of ditto.*
3. *Sholeshook Limestone Stage.*
4. *Red Hill Stage.*
5. *Slade Stage.*

Fig. 5.

Diagram-Section along Railway from Haverfordwest Station to North of Crundale.

Length of Section, 1¾ miles.



1. *Sholeshook Limestone.*
2. *Red Hill Stage.*
3. *Slade Stage.*
4. *Grit.*
5. *Lower Llandovery.(?) much folded.*

Map and Sections of Palæozoic Rocks near Haverfordwest.

Dangerfield, Lith. 22, Bedford St Covent Garden. 70245(7.85)

running eastward from Roch Castle, north also of the Pre-Cambrian ridges, parallel with this, are black iron-stained slates, weathering olive-grey or yellowish, generally dipping north. They are well seen near Leweston, Trefgarn Bridge, and Spittal Cross. At Leweston Old Mill they have yielded:—

Agnostus pisiformis, *Linn.*	Olenus spinulosus, *Wahl.*
—— ——, var. socialis, *Tullb.*	

At Trefgarn Bridge the following very important section occurs in a quarry by the roadside, close to the fourth milestone from Haverfordwest (fig. 2).

The shales are considerably disturbed, and contain a fair number of fossils of the same species as those found at Leweston Old Mill.

The conglomerate adheres to an ashy-looking rock of Pre-Cambrian (?) age, with nearly vertical divisional planes, the origin of which we were unable to determine.

The fossils found in these two localities prove that these beds are Lingula Flags. Dr. Hicks has recorded the presence of Lingula Flags about this spot (Q. J. G. S. vol. xxxv. p. 287), but gives no fossil list; and it is interesting to find that his determination of the age of the beds, based presumably upon lithological characters, is fully borne out by the fossil evidence.

To the south of the great fault, much newer beds occur, so that we are unable to record the occurrence of Tremadoc and Arenig fossils in the area under consideration.

2. *Didymograptus Shales.*—These beds occur in the complicated anticlinal to the east of Narberth, and, next to the Lingula Flags, are the oldest beds we have met with in the tract of country we have examined. They consist of black graptolite-shales of the ordinary type, crowded with "tuning-fork" *Didymograpti*, and containing also small horny brachiopods and fragments of trilobites. *Didymograptus Murchisoni* occurs in abundance. That these beds are underneath the Llandeilo limestone is shown by their occurrence in an anticlinal arch between the limestone of Llan Mill and that of Lampeter Velfry. The southern arch of this anticlinal is vertical, and even reversed in places, but it is indicated as an anticlinal in the horizontal section No. 2 of the Geological Survey. The limestone of Lampeter Velfry is a faulted synclinal, and to the north occurs another anticlinal, between Lampeter Velfry and Llandewi Velfry, and here again the *Didymograptus*-shales are found, and have yielded *Didymograpti* by the roadside west of "Ll" in "Llandewi Velfry."

The same fossils are found in similar shales near Whitland, below the limestone, but at some distance from its outcrop.

Prof. Lapworth (Ann. & Mag. Nat. Hist. Ser. 5. vol. iii. p. 59) also places the *Didymograptus*-shales of this area below the Llandeilo limestone.

3. *Llandeilo Limestone.*—The well-known black limestone of Llan Mill, Lampeter Velfry, Llandewi Velfry, &c., interstratified with black shales. It is frequently crowded with fossils, and the following

are preserved in the Geological Survey Museum from the limestone of this region:—

Monticulipora favulosa, *Phill.*	Trinucleus favus, *Salt.*
Beyrichia complicata, *Salt.*	Leptæna sericea, *Sow.*
Calymene cambrensis, *Salt.*	Orthis striatula, *Conr.*
Asaphus tyrannus, *Murch.*	&c. &c.

The limestone is also seen north of Stoneyford, on the road between Narberth and Clynderwen Station; and similar limestone, which has, however, not furnished us with any fossils, occurs at Bullhook and Camrose, as marked on the Geological Survey map.

4. *Dicranograptus Shales.*—These beds immediately succeed the Llandeilo limestone of Llandewi Velfry, and are seen above the limestone quarry at "P" in "Parsonage." They are black shales, with some grit bands, and are usually crowded with graptolites, including *Dicranograptus ramosus*, *Climacograptus bicornis*, &c. We have nowhere seen a section giving the complete series. At Llandewi Velfry there is room for about 50 feet of shales between the Llandeilo limestone and the beds above the shales, but it is very doubtful whether the whole of the shales are now represented here. The uppermost beds of the series certainly occur at this locality. They are well-defined, flaggy and sandy black shales, characterized especially by the abundance of *Orthis argentea*, His., and may therefore be spoken of as the zone of *Orthis argentea*.

Dr. Hicks (Q. J. G. S. vol. xxxi. p. 178) also places the Llandeilo limestone between the *Didymograptus*- and *Dicranograptus*-shales.

Confirmatory sections.—The *Dicranograptus*-shales are exposed to a considerable extent to the north of the complex synclinal.

On the west side of the Western Cleddau, they occur much folded in the neighbourhood of Camrose, and at Camrose Mill the *Dicranograptus* beds are again seen succeeding the Llandeilo limestone. At Wolfsdale they have yielded *Ogygia Buchii*. On the east side of the Western Cleddau the beds set in at Rudbaxton, and we have found graptolites at Green Plain, south of Trefgarn Bridge. At Clarbeston-Road Station also graptolites occur. The beds can then be traced in several sections along the railway as at Pendwr, Longridge Bridge, and Blaen Waen, between Clarbeston-Road and Clynderwen Stations, and they appear to overlie the Llandeilo limestone south of Bullhook, although the two are not in close proximity. These beds are also brought up by folds to the south of this. North of Stoneyford they lie immediately over the Llandeilo limestone. The *Orthis-argentea* zone is seen near Grondre, at Robeston Wathen, and at Prendergast, but no Llandeilo limestone is exposed at these places.

We have then several independent sections showing the *Dicranograptus*-shales immediately succeeding the Llandeilo limestone, and the latter may, indeed, be looked upon as merely a calcareous development of the black shales which occur below, within, and above it.

The fossils, other than graptolites, of the *Dicranograptus*-shales, occur chiefly in the *Orthis-argentea* zone, with the exception of

Ogygia Buchii. In that zone we find *Turrilepas* sp., *Pleurotomaria* and *Orthoceras*. *Siphonotreta micula* also occurs in abundance, as well as in lower zones, and other horny brachiopods are common.

5. *Robeston Wathen Limestone*.—This deposit is best known as occurring at the village of Robeston Wathen, where a quarry to the north of the church contains a black limestone with interbedded black shales, dipping S.S.W. The calcareous bands are crowded with *Halysites catenularius*, and other fossils occur, including *Orthis elegantula*, Dalm. Trilobites are rare and fragmentary.

(It is to be noticed that many of the fossils from this locality in the Jermyn-Street Museum are not from this limestone, but from higher beds, to be described presently.)

As the section here is an important one, a figure of it is added (Pl. XV. fig. 3).

The graptolite-shales are seen by a stream immediately below the quarry, dipping under the limestone. These shales belong, as stated above, to the *Orthis-argentea* zone, and the limestone itself appears to be a calcareous development of the upper part of these shales.

Confirmatory Sections.—Near Grondre, two miles north-west of Robeston Wathen, the same limestone is seen, as represented on the Geological Survey map. It is crowded with *Halysites*, as at Robeston Wathen, and is here nearly vertical. In a quarry, at this place, the black limestone is associated with an ashy-looking limestone which yielded a cystidean, and which is apparently the representative of the lowest stage of the next series; but the relations of the two were not determined. Fossils of the black limestone at Grondre:—

Syringophyllum organum, *Linn.*
Halysites catenularius, *Linn.*
Petraia æquisulcata, *M'Coy.*
Illænus Bowmanni, *Salt.*
Orthis Actoniæ, *Sow.*

To the north-east of the limestone quarry, in a small quarry in a field close to Grondre farm, the *Orthis-argentea* shales are dipping north. The limestone strikes as though it would pass above the shales. The tract between Grondre and Robeston Wathen is much disturbed, newer beds being faulted and folded in.

At Llandewi Velfry, the *Orthis-argentea* shales, which occur some way above the Llandeilo limestone, pass up into flaggy black limestone like that of Robeston Wathen.

At Fron, 1¾ mile north-east of Llandewi Velfry, where the Llandeilo limestone is not seen, the *Orthis-argentea* shales are found in a small roadside exposure, dipping a little north of west; and on the hill-side to the west of this and above it, black limestone is exposed in a quarry, presenting an appearance quite similar to that of Robeston Wathen, also with abundance of *Halysites*, and amongst other fossils the following:—

Heliolites interstinctus, *Wahl.*
—— dubius, *Schmidt.*
Petraia æquisulcata, *M'Coy.*
—— elongata, *Phill.*
Illænus Bowmanni, *Salt.*
Glauconome disticha, *Goldf.*
Orthis Actoniæ, *Sow.*
—— calligramma, *Dalm.*
Leptæna transversalis, *Wahl.*
Strophomena rhomboidalis, *Wilck.*

At Prendergast, north of Haverfordwest, the *Orthis-argentea*

shales are seen in a lane north of the church, dipping north, and they are very flaggy and calcareous towards the summit, but limestone bands do not occur as in the above localities.

The section seen in this lane, and in a quarry immediately to the east of it, is shown in Pl. XV. fig. 4.

6. *Trinucleus-seticornis Beds.*—These are subdivided into three stages, viz.:—

(*a*) Sholeshook limestone.
(*b*) Redhill shales.
(*c*) Slade calcareous shales.

The beds succeeding the Robeston Wathen limestone consist mainly of blue-grey shales, weathering olive-green, with a considerable development of calcareous matter at the base and summit.

The form *Trinucleus seticornis*, or its variety *Bucklandi*, occurs throughout, and is very characteristic of these beds, which may therefore be spoken of as the *Trinucleus-seticornis* beds.

(*a*) *Sholeshook Limestone.*—At Robeston Wathen, the central part of the quarry, as shown in the section (fig. 3), contains the upper portion of these beds immediately succeeding the Robeston Wathen limestone. It differs considerably from that limestone both lithologically and palæontologically. Whereas the black limestone is evidently a calcareous development of the black shales, the calcareous band we are now considering is no less clearly a member of the blue-grey shales; and this is also true of the lower zones which occur in other localities. The following fossils occurred in this calcareous band:—*Heliolites interstinctus*, Wahl., *Glyptocrinus basalis*, M'Coy, *Trinucleus seticornis*, His., *Phacops Brongniarti*, Portl., *P. alifrons* ?, *Holopella*, *Orthoceras*.

The actual limestone appears to have been crushed out at this point, the fossils occurring in calcareous shales which are elsewhere seen immediately above the limestone itself.

Confirmatory Sections.—At Prendergast, as seen in fig. 4, the uppermost member of the *Orthis argentea* beds, which is there calcareous, is succeeded by greenish, impure limestone, crowded with fossils, especially trilobites, although the limestone itself is much crushed. The fossils are similar to those of Robeston Wathen, but are much more abundant. The following occur:—

Halysites catenularius, *Linn.*
Petraia.
Crinoid and cystoid fragments.
Tentaculites anglicus, *Salt.*
Phacops mucronatus, *Brongn.*, var.
—— alifrons, *Salt.* ?
Cheirurus bimucronatus, *Murch.*
—— juvenis, *Salt.*
—— octolobatus, *M'Coy.*
Lichas laxatus, *M'Coy.*
Stygina.
Cybele verrucosa, *Dalm.*
Illænus Bowmanni, *Salt.*
Homalonotus ?
Trinucleus seticornis, var. Bucklandi, *Barr.*
Agnostus trinodus, *Salt.*
Orthis elegantula, *Dalm.*
Leptæna quinquecostata, *M'Coy.*
—— sericea, *Sow.*
—— tenuicincta, *M'Coy.*
Strophomena rhomboidalis, *Wilck.*
Ctenodonta ?
Bellerophon bilobatus, *Sow.*
Orthoceras.
Cyrtoceras sonax, *Salt.*

At Sholeshook a splendid section is exposed in the railway-

cutting. The beds here are of the same nature as at Prendergast, but the calcareous matter is mainly collected into nodules. The general dip is northerly, and the beds which appear to dip under the Sholeshook limestone are probably newer beds brought down by a faulted overfold. To this part we shall refer presently. Although the Sholeshook section does not assist us in determining the relationship of this calcareous band to the older beds, it is important as containing so many fossils, and being a well-known fossil locality. The following list of fossils from this place is compiled from the specimens in the Jermyn-Street Museum, those collected by ourselves, and those noticed by Törnquist (Öfv. af K. V.-A. Förhandl. Stockholm, 1879, No. 2, p. 70).

Favosites fibrosus, *Goldf.*
Chætetes petropolitana, *Pand.*
Cystideans (cf. Mem. Geol. Surv. vol. iii.).
Beyrichia strangulata, *Salt.*
Agnostus trinodus, *Salt.*
Ampyx tumidus, *Forbes.*
Trinucleus seticornis, *His.*
—— ——, var. Bucklandi, *Barr.*
Remopleurides longicostatus, *Portl.*
—— radians, *Barr.*
—— dorso-spinifer, *Portl.*
Stygina latifrons, *Portl.*
Illænus Bowmanni, *Salt.*
Lichas laxatus, *M'Coy.*
Calymene fatua, *Salt., MS.*
Cyphaspis megalops, *M'Coy.*
Phillipsia parabola, *Barr.*
Cybele verrucosa, *Dalm.*
—— Loveni, *Linnrs.*
Encrinurus sexcostatus, *Salt.*
Cheirurus bimucronatus, *Murch.*
—— octolobatus, *M'Coy.*
—— juvenis, *Salt.*
Sphærexochus boops, *Salt.*
—— angustifrons, *Ang.*
Phacops aratus, *Salt., MS.*
—— Brongniarti, *Portl.*
Glauconome, n. sp.
Leptæna sericea, *Sow.*
—— tenuicincta, *M'Coy.*
Orthis testudinaria, *Dalm.*
—— calligramma, *Dalm.*
Cyrtoceras sonax, *Salt.*
Trochoceras cornu-arietis, *Sow.*

At the schoolhouse north of Pelcomb Cross (3 miles north-west of Haverfordwest), the *Orthis-argentea* shales are seen by a small stream to the west of the road, dipping in a southerly direction. South of this, a quarry by the roadside contains beds apparently overlying the *Orthis-argentea* shales. These consist of crushed calcareous shales of a greenish colour, quite like those of Sholeshook and Prendergast. There is room between the *Orthis-argentea* shales and the quarry for the Robeston Wathen limestone, but no exposure is seen. This quarry is probably the place from which Prof. Phillips obtained the fossils mentioned in 'Memoirs of the Geological Survey,' vol. ii. pp. 235 *et seq.* The following occur here:—

Agnostus trinodus, *Salt.*
Ampyx tumidus, *Forbes.*
Cybele Loveni, *Linnrs.*
Encrinurus sexcostatus, *Salt.*
Illænus (young).
Cheirurus bimucronatus, *Murch.*
Staurocephalus globiceps, *Portl.*
Phacops Brongniarti, *Portl.*
Phillipsia parabola, *Barr.*
Trinucleus seticornis, var. Bucklandi, *Barr.*

These beds can be traced to the north of West Pelcomb, where similar fossils are found, and *Trinucleus Bucklandi* is specially abundant, and well preserved. *Cheirurus juvenis* also occurred here.

On the north side of the complex synclinal, calcareous beds are seen by the platform on the south side of Clarbeston-Road Station, where *Trinucleus Bucklandi* is found in plenty with:—

Phacops Brongniarti, *Portl.*
Homalonotus?
Leptæna tenuicincta, *M'Coy.*

On the north platform, the *Dicranograptus*-shales are seen, dipping as though to pass under the calcareous beds, and a small thickness of these occurs on the south side, just at the east end of the platform. Although the two series are there seen in apposition, a small fault must occur along the line of strike, cutting out the greater part of the calcareous beds; for the summit of the graptolite-shales (the *Orthis-argentea* zone), the Robeston Wathen limestone, and the lower part of the Sholeshook limestone stage are absent.

(*b*) *Redhill Beds.*—We have named these beds after the farm of Redhill, two miles north of Haverfordwest, where a quarry by the roadside shows a good section of the beds, which are also fairly fossiliferous here. (As a general rule, fossils are somewhat scarce in them.) They consist of blue-grey shales, weathering olive-green. In all cases where the Sholeshook limestone is seen, it is found to pass gradually up into these beds by disappearance of the calcareous material. We have obtained fossils from the Redhill beds, at Redhill, Pelcomb Bridge, and Wolfsdale Well, on the west side of the Western Cleddau; and at Prendergast Mill, Crundale, and Robeston Wathen, on the east side of that river. The list here given shows the principal fossils obtained from these localities:—

	Redhill Quarry.	Pelcomb Bridge.	Wolfsdale Well.	Prendergast Mill.	Crundale.	Robeston Wathen.
Chætetes, sp.					*	
Stenopora, sp.					*	
Crinoid, arms of	*				*	
Phacops mucronatus, *Brongn.*, var.	*					
—— alifrons, *Salt.* ?	*					
—— Brongniarti, *Portl.*	*	*		*	*	*
Calymene, sp.					*	
Trinucleus Bucklandi, *Barr.*	*					
Ampyx rostratus, *Sars.*			*			
Homalonotus bisulcatus, *Salt.*	*					
Encrinurus, sp.		*				
Lingula		*				
Leptæna sericea, *Sow.*	*	*				
—— tenuicincta, *M'Coy.*	*					
Strophomena rhomboidalis, *Wilck.*					*	
Orthis elegantula, *Dalm.*					*	
—— calligramma, *Dalm.*	*					
Modiolopsis?				*		
Arca dissimilis, *Portl.*				*		
—— transversa, *Portl.*				*		
Holopea concinna, *M'Coy*	*					
Pleurotomaria, sp.	*					
Bellerophon, sp.				*		
Ecculiomphalus Bucklandi, *Portl.*			*			
Orthoceras gracile, *Portl.*	*					
Cyrtoceras, sp.	*					

The large tract of country west of the Western Cleddau occupied by these Redhill beds, is due to frequent repetition by folds, and the

same has taken place, but to a less extent, on the east side of the river.

(*c*) *Slade beds.*—These succeed the Redhill stage at Lower Slade, immediately north of Haverfordwest, on the west side of the Western Cleddau. They are seen by the roadside, and also in a cutting near the mill. From the latter place, we have examined a number of fossils presented to the Woodwardian Museum by Dr. Hicks. To the south they are faulted against Lower Llandovery beds, the fault being seen in section in the road-cutting.

The beds consist of gritty green shales, with weathered calcareous bands, very similar in lithological character to the well-known Lower Llandovery beds of this district, but the fossils are to a considerable extent different. *Trinucleus seticornis* is fairly common, and has never been found in the Lower Llandovery beds of this area. Many calcareous bands of this stage are crowded with *Phyllopora Hisingeri*, M'Coy. Among the fossils at Slade are:—

Stenopora, sp.
Glyptocrinus basalis, *M'Coy.*
Tentaculites anglicus, *Salt.*
Calymene Blumenbachii, *Brongn.*
Phacops Brongniarti, *Portl.*
Illænus Murchisoni, *Salt.* ?
—— Bowmanni, *Salt.*
Homalonotus bisulcatus, *Salt.*
Trinucleus seticornis, *His.*
Glauconome disticha, *Goldf.*
Lingula.
Strophomena rhomboidalis, *Wilck.* ?
—— corrugatella, *Dav.*
Leptæna sericea, *Sow.*
Orthis biforata, *Schloth.*
—— elegantula, *Dalm.*
—— testudinaria, *Dalm.*

On the east side of the Western Cleddau, these Slade beds occur in a lane north of Crundale, dipping away from the Redhill beds of that locality, which appear to pass under them. They are there very fossiliferous, and have yielded *Trinucleus seticornis* along with:—

Petraia, sp.
Tentaculites anglicus, *Salt.*
Phyllopora Hisingeri, *M'Coy.*
Calymene trinucleina, *Linnrs.*?
Orthis testudinaria, *Dalm.*
Bellerophon bilobatus, *Sow.*

These beds are very extensively exposed in this region, being found also in the railway-cuttings at Little Hareshead and Clover Hill, and in a small quarry at Dallaston.

At Robeston Wathen they occur above the blue-grey shales of the Redhill stage; and on the other side of the Robeston Wathen synclinal, are seen at Benlomond Cottage, where Prof. Phillips found *Trinucleus ornatus*, var. *Caractaci* (Mem. Geol. Survey, vol. ii. p. 240).

Fossils from the north side of the Robeston Wathen synclinal are:—

Climacograptus.
Petraia.
Tentaculites anglicus, *Salt.*
Ptilodictya costellata, *M'Coy.*
Calymene trinucleina, *Linnrs.* ?
Trinucleus seticornis, *His.*
Cheirurus, sp.
Phacops Brongniarti, *Portl.*
Illænus.
Orthis porcata, *M'Coy* ?
Leptæna sericea, *Sow.*
Strophomena.
Bellerophon bilobatus, *Sow.*

From Benlomond Cottage:—

Tentaculites anglicus, *Salt.*
Lichas.
Orthis calligramma, *Dalm.*
Orthis testudinaria, *Dalm.*
Leptæna sericea, *Sow.*

North of Stoneyford, the beds of this stage are also seen in the southern limb of a small synclinal, the lower beds of which are apparently absent, owing to a slight dislocation.

To the east of this, the same beds are found occupying the more central part of the synclinal north of Llandewi Velfry.

7. *Conglomerate Series.*—Near the centre of the complex synclinal, and in the centres of the minor synclinals of Robeston Wathen, Penblewin, and to the north of Llandewi Velfry, a coarse conglomerate is found with pebbles of vein quartz, and other materials of distant origin, succeeded by a coarse quartzose grit.

To the west, this grit appears to be first met with in the railway-cutting south of Sholeshook, where it is faulted in against older beds on the north. To the east of this, it is seen near Maryborough, dipping north at a low angle. From here it runs eastward along a ridge to Wiston Wood. In a quarry south-west of Valley Farm, green-banded mudstones, with beds of quartz-grit, possibly belonging to this series, are found. On the north side of the quarry they dip at a very low angle to the north, whilst on the south side they are vertical. This appears to be due to a sudden bend rather than to a fault. To the west of Wiston Wood, the conglomerate is exposed in a quarry in a field. It is here nearly vertical, but dips slightly north, and, according to the strike, would pass beneath the beds of the last-mentioned quarry.

Another ridge of grit runs to the north of this one, also in a general east and west direction. It is seen faulted against *Trinucleus-seticornis* shales, in the railway-cutting, west of Wiston Mill. Proceeding in an easterly direction, we again find it exposed on the ridge $\frac{1}{3}$ mile S. of "o" in "Dallaston;" it is here much disturbed. It appears to be continued along this ridge to Wiston. In a quarry south of Church Hill, near this village, a very coarse grit is found, dipping south. Wherever exposed, the grit of this ridge appears to overlie or be faulted against beds of the Slade stage.

A third grit-ridge runs parallel to these, and to the south of them. Grit is found, apparently overlying green shales, in a road-cutting west of Slebech New Church. In a quarry south of Clerken Hill, east of the last place, conglomerate is exposed, dipping north.

At Robeston Wathen the conglomerate is many feet thick, and occupies the centre of the synclinal shown in fig. 3. In each limb of the synclinal it rests upon the representatives of the Slade beds, containing *Trinucleus*.

A patch of grit is seen in a quarry south of "Camp," $1\frac{1}{4}$ mile north-east of Robeston Wathen. The relations of this to the surrounding beds are somewhat obscure, as the tract of country between the limestones of Robeston Wathen and Grondre is, as already stated, much broken.

Another ridge runs from near Penblewin eastward. Here the conglomerate is found in a quarry west of Carmine, dipping north at an angle of 20° and succeeded by coarse grit. It rests upon the representatives of the Slade beds which occur at the cross roads at Penbelwin.

The last appearance of the conglomerate eastward, in the area we have examined, is in a quarry west of Wheelabout, where it is succeeded by sandstone, the beds dipping N.W. It occurs at this place also above beds of the Slade stage, which are well seen at the "k" of "Bank Saison" dipping west.

From the numerous exposures of the beds of this series, where they immediately succeed the Slade beds, there seems little doubt that this is the true position of the conglomerate; and as we have found no evidence of its resting upon any beds lower in the series, it would seem that there is no very great physical discordance at the base of the conglomerate-band, which nevertheless may mark an important physical change in the area.

We have unfortunately been unable to find any exposures showing the conglomerate succeeded, without suspicion of faulting, by still higher beds, as it occurs in most cases on the summits of ridges, and the higher strata have been removed by denudation. In one instance, however, the grit is found between the Bala and the fossiliferous Lower Llandovery beds. This is in a section, previously alluded to, on the railway between Haverfordwest station and Sholeshook. The diagram section (fig. 5) shows the actual exposures, and the fault and folds which we consider necessary to explain the apparent sequence. Between the Sholeshook limestone and the grit only one isolated exposure is seen, in a lane east of the railway, having beds lithologically like those of the Slade stage, and containing fossils which are too imperfect for determination. The beds between the grit and the station are also somewhat unfossiliferous, and though the fossils found, including *Phacops mucronatus*, Ang. (the form which occurs in the Upper Brachiopod beds of Sweden, and not the variety of the Sholeshook and Redhill beds), seem to indicate the Lower Llandovery age of the beds, the determination is doubtful. We can, however, draw no line between these beds and the very fossiliferous beds of the Gas-works, of true Lower Llandovery age.

Another point to be noticed is the absence of the conglomerate, which, however, occurs in connexion with the grit, further east, as above described. Its absence appears to point to the existence of a fault, as well as the inversion represented in the diagram. The relationship of the conglomerate series to the Lower Llandovery further east is obscure, owing to the paucity of sections. From the nature of the ground, we should expect this series to pass continuously round from Wiston to Slebech, thus lying between the Lower Llandovery and the Bala beds which occur further east.

What scanty evidence we have, therefore, certainly points to the conglomerate series being immediately succeeded by the fossiliferous Lower Llandovery beds, and this conclusion is supported by the palæontological evidence; for the fauna of the Slade beds, though differing from that of the Lower Llandovery beds, has several forms in common.

Moreover, the accumulation of the conglomerate series shows only a slight pause in a period during which beds of similar litho-

logical character were being laid down, as the Lower Llandovery beds closely resemble the Slade beds lithologically.

8. *Lower Llandovery Beds.*—These beds are, as explained above, apparently faulted against the lower beds in the immediate neighbourhood of Haverfordwest. They are usually very highly inclined, and stretch to the south of the town for nearly two miles. The well-known section at the Gas-works shows the general character of the rocks, which consist of gritty green shales, with bands of grit, and weathered calcareous bands crowded with fossils. As the organisms of this deposit are preserved in many museums, it is unnecessary to give a full list. *Nidulites favus*, *Petraia subduplicata* var. *crenulata*, *Tentaculites anglicus*, and brachiopods, lamellibranchs, and gasteropods are all abundant. Amongst the fossils hitherto unrecorded from these beds are *Phacops elegans*, Bœck and Sars (=*elliptifrons*, Esm.), and *Deiphon Forbesi*, Barr. A fine specimen of the latter was presented to the Woodwardian Museum by Mr. H. T. Wills.

§ 3. *Comparison with the Deposits of other Areas.*

The resemblance of many of our stages to those of other areas, whether we take into account their lithological or palæontological characters, is so striking, that it cannot be a mere coincidence, especially as this resemblance does not occur in isolated stages, but in the consecutive stages of some of the series. We propose, therefore, to point out briefly some of these similarities, as they afford assistance in attempting the correlation of deposits of different areas.

i. *Lingula-Flags.*—These beds appear, from the occurrence of *Olenus spinulosus*, to represent the Lower Dolgelly beds of the Lingula-Flags of North Wales, which are correlated by Prof. Brögger (Sil. Et. 2 and 3, p. 144) with his "*Parabolina-spinulosa* niveau" (2 *b*) in the Christiania district, where that fossil is likewise associated with *Agnostus socialis*.

It is desirable, however, that additional species should be obtained; for whilst the fossils already procured leave no doubt as to the Lingula-Flag age of the rocks containing them, it is perhaps dangerous to attempt to assert positively to what portion of the Lingula-Flag series they belong, without further evidence.

ii. *Didymograptus-Shales.*—The "tuning-fork" graptolites of these beds are characteristic of Dr. Hicks's Llanvirn beds in the St.-David's district, as elsewhere. As the horizon is so well known in many places, and contains this particular type of graptolite, it is needless to give a list of deposits of the same age in other areas.

iii. *Llandeilo Limestone.*—The remark just made applies in this case also. The position of the *Asaphus-tyrannus* beds is well established in South Wales. At the same time it is possible that the beds included in the Llandeilo limestone of other regions are partly represented by the lower beds of the succeeding division of the Haverfordwest district; for whereas *Ogygia Buchii* has not been discovered by us in the limestone, and is apparently not recorded

from the limestone of this region, it does occur in the graptolite-shales of the succeeding group.

iv. *Dicranograptus-Shales.*—It has already been stated that several zones must be represented among these beds, and that we have been unable to work these out in the field, owing to the absence of exposures continuous throughout the series. That the beds do represent generally the Glenkiln and lower portions of the Hartfell groups of Scotland appears probable; but as we have submitted a large collection of specimens from this horizon to Professor Lapworth, we leave the fuller determination of the age of the group to him.

The uppermost bands, which are crowded with *Orthis argentea*, may be compared with the *Orthis-argentea* zone of Dr. Linnarsson in Sweden (*cf.* Lapworth, Geol. Mag. dec. ii. vol. vii. p. 43).

v. *Robeston-Wathen Limestone.*—The fossils of this limestone are certainly of Middle Bala facies; but trilobites are rare, and the organisms are chiefly corals. The identification of this bed with parts, at any rate, of the Bala and Coniston limestones receives strong support from the evidence furnished by the succeeding deposits.

vi. *Trinucleus-seticornis Beds.*

(*a*) *Sholeshook Limestone Stage.*—This is comparable both lithologically and palæontologically with the Rhiwlas limestone of Bala, which must certainly be of different age from the true Bala limestone. The bed is so peculiar in character, and maintains its appearance and palæontological characters so uniformly over a wide area, that it is very easy to identify, and forms therefore a very important horizon for purposes of comparison. The Rhiwlas cystideans are similar to those of Sholeshook, and the trilobites are mostly of the same species. *Staurocephalus* is present at Rhiwlas as in Pembrokeshire, and associated with it are the following fossils of the Sholeshook stage:—

Ampyx tumidus, *Forbes.*	Trinucleus seticornis, *His.*
Cheirurus juvenis, *Salt.*	Leptæna tenuicincta, *M'Coy.*
—— bimucronatus, *Murch.*	Cyrtoceras sonax, *Salt.*

It may be observed that, as Professor Sedgwick made his Upper Bala series to include the beds above the Bala limestone, this stage must be taken as the base of that series, and it forms, as observed, a readily recognized base.

In the Lake-district a bed of quite similar lithological character occurs immediately above the Coniston Limestone. Its fauna has not yet been fully described, but one of us has elsewhere noticed it ('Sedgwick Essay,' 1882, p. 58). *Staurocephalus* is there associated with the same cystideans as at Sholeshook, and a large number of trilobites are common to the two deposits, and do not occur in the underlying Coniston limestone.

The starfish-bed of Prof. Lapworth (Q. J. G. S. vol. xxxviii. p. 619) may possibly be the representative of this in the Girvan area; it also contains *Staurocephalus globiceps*.

In Ireland the same group of fossils appears to occur at Desert-

creat, Tyrone, judging from an examination of the specimens preserved in the Museum of Practical Geology. Amongst the fossils common to Sholeshook and Desertcreat are :—

Phacops Brongniarti, *Portl.*	Illænus Bowmanni, *Salt.*
Staurocephalus globiceps, *Portl.*	Stygina latifrons, *Portl.*
Remopleurides dorso-spinifer, *Portl.*	Trinucleus seticornis, *His.*

The absence of cystideans at Desertcreat is noticeable.

A large number of fossils are recorded from this Irish locality, which seem to show that the representatives of the Redhill stage occur there also.

In Sweden the same fauna appears at the same horizon in beds of precisely similar lithological character. Immediately above the beds correlated with the Middle Bala series, in Westrogothia, Dr. Linnarsson's *Staurocephalus*-beds (at the base of the Brachiopod-schists) contain *Staurocephalus clavifrons*, Ang., *Proetus brevifrons*, *Phacops mucronatus*, *Calymene tuberculata*, *Acidaspis centrina*, *Trinucleus Wahlenbergi*, *Agnostus trinodus*, *Phillipsia parabola*, and *Panderia megalophthalma* (Linnarsson, 'Om Vestergötlands Cambriska och Siluriska Aflagringar,' p. 51).

In Scania also the same bed occurs. Dr. Tullberg ('Skånes Graptoliter,' i. p. 17) records in his zone with *Staurocephalus clavifrons* :—

Staurocephalus clavifrons, *Ang.*	Ampyx tetragonus, *Ang.*
Phacops mucronata, *Ang.*	Phillipsia parabola, *Barr.*
Trinucleus Wahlenbergi, *Rouault.*	Acidaspis, sp.
Illænus, *cf.* Salteri, *Barr.*	Calymene Blumenbachii, *Brongn.*, var.
Proetus brevifrons, *Ang.*	Agnostus trinodus, *Salt.*
Cheirurus, sp.	Dentalium, sp.
	Turbo, sp.

From the general occurrence in this zone of *Staurocephalus globiceps*, or a closely allied species, it may be conveniently spoken of as the *Staurocephalus*-zone.

(*b*) *Redhill Stage.*—This stage is lithologically like the Ashgill shales of the Lake-district, which also immediately overlie the *Staurocephalus*-zone. In Scotland the "soft blue mudstones, homogeneous, thick-bedded, and more or less concretionary in structure," described by Prof. Lapworth as occurring above the Starfish-bed of Lady Burn, in the Girvan area, seem to be likewise similar (Q. J. G. S. xxxviii. p. 619).

In Scandinavia the beds with *Phacops eucentra*, Ang. (a variety of *P. mucronatus* ?), which immediately succeed the *Staurocephalus*-zone in Scania and Westrogothia, have elsewhere (Q. J. G. S. xxxviii. p. 321) been compared by one of us with the Ashgill Shales of Britain.

(*c*) *Slade Beds.*—These are not precisely like any beds known to us as occurring about the same horizon in other areas.

In the Lake-district a mottled grey limestone with many brachiopods occurs immediately above the Ashgill Shales and below the Birkhill beds in Skelgill Beck. Like the Slade beds, it is marked by the occurrence of *Climacograptus* and the absence of *Monograptus.*

In Scania, Dr. Tullberg ('Skånes Graptoliter,' i. p. 17) finds above his zone with *Phacops mucronatus* (*P. eucentra*) a zone with *Diplograptus* and *Climacograptus scalaris*, and marked by an absence of *Monograptus*. This zone he places at the top of the Upper Cambrian (Sedgwick), and not at the base of the Silurian, where Prof. Lapworth describes a zone marked by the absence of *Monograptus*, viz. at the base of the Birkhill beds (*cf.* Lapworth, Q. J. G. S. vol. xxxiv. p. 318).

In Westrogothia the gritty beds with *Trinucleus* at Mösseberg may represent our Slade beds.

vii. *The Conglomerate.*—As stated, when describing the apparent position of these beds, they appear to succeed everywhere the Slade beds.

If this be their true position, they form a satisfactory base to the Silurian rocks of this area.

We may compare them with the Mullock-Hill conglomerate of Prof. Lapworth (Q. J. G. S. vol. xxxviii. p. 621), which lies in the Girvan district directly above the *Trinucleus*-shales, just as the conglomerate in the district now described lies above our *Trinucleus*-shales.

viii. *Lower Llandovery Beds.*—We have applied this term to the shelly sandstones immediately south of Haverfordwest town, as they have been constantly spoken of as Lower Llandovery. If they do actually succeed the Conglomerate stage, the latter should also be included in the Lower Llandovery series.

These shelly sandstones are lithologically and palæontologically similar to two well-known deposits, viz. the Mullock-Hill Sandstones of the Girvan district, and stage 5 β in the neighbourhood of Christiania. All these contain *Nidulites* along with *Stricklandinia* and a host of other brachiopods. A comparison of the published lists will show the practical identity of the faunas (*cf.* Catalogues of Palæozoic Fossils in the Woodwardian Museum, and that of Practical Geology, also Kjerulf's 'Veiviser').

The upper part of the Brachiopod-beds of Westrogothia has a similar fauna, and is placed on this horizon by the Scandinavian geologists.

One of us has in a previous communication (Q. J. G. S. vol. xxxviii. p. 316) discussed the age of the *Leptæna*-limestone of Mr. Törnquist, which occurs in Dalecarlia, and has referred it to a position above the *Lobiferus*- and *Retiolites*-shales of that region. This was certainly a mistake, due to ignorance of the phenomena presented by a greatly disturbed region at the time of examination.

Dr. Fr. Schmidt has shown (Q. J. G. S. vol. xxxviii. p. 523) that the fauna of the stage F of the East Baltic provinces is that of the *Leptæna*-limestone of Osmundsberg.

The *Leptæna*-limestone contains a mixture of faunas of several of the Haverfordwest beds, viz. :—the Lower Llandovery, *Trinucleus-seticornis* beds, and perhaps even of the Robeston-Wathen limestone, the corals of which also occur in the *Leptæna*-limestone.

§ 4. *Conclusion.*

We have endeavoured, in this paper, to establish the succession in the district under consideration. That certain difficulties are not yet cleared up is admitted. Our inability to discover any section showing normal Sholeshook limestone resting upon normal Robeston-Wathen limestone is unfortunate. In separating these stages from each other, we are influenced by the lithological and palæontological differences between the two deposits, and by comparison with similar beds in other areas. But for this, we should be disposed to look upon the Robeston-Wathen limestone as a local development of the Sholeshook limestone. We may note, however, that there are many places in the district where one or more of the limestones can be satisfactorily proved to have been crushed out.

As already explained, also, the relation of the conglomerate to the succeeding beds requires further study.

These minor difficulties have been encountered when studying portions of the sequence which are typically developed elsewhere. As they do not greatly affect our establishment of the sequence in this area, and as other difficulties would probably arise upon further exploration, the announcement of our results might be indefinitely postponed, and we therefore venture to bring our work before the Society, in the belief that what we have done will prove sufficient to furnish a clue to the solution of a very interesting question, viz. the nature of the foldings which have affected the district.

EXPLANATION OF PLATE XV.

Fig. 1. Geological Sketch-Map of the neighbourhood of Haverfordwest. The map, based on that of the Geological Survey, is simply intended as a sketch-map, showing the general distribution of the beds; and the boundaries in many places are only approximately correct. The Redhill beds and Slade beds have been represented by the same sign, as we have not traced the boundary between them over the whole district. The *Dicranograptus*-shales of Grondre and Longford may extend further east than represented.
2. Section in Quarry south-east of Trefgarn Bridge.
3. Section through Robeston Wathen.
4. Section in the Lane north of Prendergast Church.
5. Diagram-section along the Railway from Haverfordwest Station to north of Crundale.

Discussion.

The President expressed his pleasure at seeing that such admirable work had been done by Cambridge geologists.

Dr. Hicks stated that the Authors had entirely confirmed his views that the rocks of Roch Castle and Trefgarn which he had referred to the Archæan were not, as believed by the Geological Survey, intrusive rocks penetrating Lower-Silurian strata. The recognition of the important fact that these are of Pre-Cambrian age was absolutely necessary before the geology of the area could

possibly be interpreted. The succession of the rocks in this district had never been unravelled till the Authors undertook the task.

Prof. Hughes remarked on the absence of the evidence of the occurrence of the Harlech Grits except the basement-bed, of the Menevian, the Tremadocs, part of the Arenigs, and other formations. He thought the Hirnant limestone really consists of two members which are separated by a great break, and the lower of these only is represented by a limestone in the area described. He thought it probable that the equivalents of the Upper Conglomerates might be found in the Malvern district, and that they form the base of the Silurian.

Mr. Marr thought that the beds in Trefgarn-Bridge Quarry exhibit signs of faulting, which may account for the apparent absence of some of the strata. He thought that a great confusion had arisen as to the position of the conglomerates at the base of the Silurian.

36. General Section *of the* Bagshot Strata *from* Aldershot *to* Wokingham. By the Rev. A. Irving, B.Sc., B.A., F.G.S. (Read April 15, 1885.)

A residence of some years in the Bagshot district of the London Basin has afforded me opportunities for many observations on the Bagshot strata which have escaped the notice of previous writers on the subject. Some of these have been already recorded *. Two or three years ago I was led to investigate the origin of the green colouring-matter so prevalent in the Middle and Lower Bagshot strata, and an account of the results arrived at was given in the 'Geological Magazine' †, the bearing of the facts upon the question of water-supply being shown to be of some economic importance. More recently ‡ I have given some results obtained by a further prosecution of the same line of inquiry, and have stated that they have led me to regard the Middle and Lower Bagshot strata as, upon the whole, a series of *delta*-, *marsh*-, and *lagoon*-deposits, such as are now forming in the alluvial flats at the mouth of many a large river, but those of the Upper Bagshot as the deposits of a marine *estuary*, which covered up and overlapped the Middle and Lower series, so as to have extended over parts of the London Clay. This inference from chemical and physical evidence is at variance with the generally received view as to the physical history of these strata, the first eminent worker on these beds having declared that they were conformable to the London Clay §, and the Geological Survey having mapped the district in accordance with such a supposition.

The main object of this paper is to bring before the Society stratigraphical evidence on this question. It must be understood that I make no attempt here to *correlate* the strata of our Bagshot district in detail with the corresponding strata of the Hampshire Basin: I use the terms 'Upper,' 'Middle,' and 'Lower,' therefore, as applied to the Bagshot strata, in their natural sense, to mean the well-marked upper, middle, and lower divisions of the latest Eocene formation of the district to which it owes its name, regarding this as a distinct area of deposition in Bagshot times.

In the classification of the Bagshot beds I have included the bed of loamy sand (No. 4, figs. 1 & 2), which occurs so generally immediately above the green sands and clays, in the Middle Division (as was done by the Survey); the pebble-bed, however, which commonly

* See Proceedings of the Geologists' Association, vol. viii. pp. 143–173.

† See Geol. Mag. dec. ii. vol. x. pp. 404–413.

‡ *Ibid.* dec. iii. vol. ii.

§ See Prestwich, Quart. Journ. Geol. Soc. vol. iii.

occurs next above it, appears to have been overlooked by the Surveyors, though it crops out in many places. There is some indication of considerable contemporaneous erosion in some sections where the pebble-bed rests upon this loamy bed; and *in the bed itself thin seams of pipe-clay generally occur.* On this last point, it would seem, my observations differ from those of the Surveyors *. Grains of quartz coated with black and green amorphous matter of vegetable origin are scattered freely in this bed: they are especially numerous in juxtaposition with the pipe-clay layers.

Detailed Sections.

As these are rather numerous, and are spread over a rather large area, extending about 13 miles from north to south, it will tend to simplify matters if we consider these sections in two series:—*a.* Deep-well sections, giving the whole range of the Bagshot Sands, and in some cases the London Clay as well; *b.* Sections in which only portions of the Bagshot Sands are exposed. We shall find the general character of the three divisions of the Bagshot strata sufficiently determined by the evidence afforded by the former series to aid us considerably in determining the stratigraphical horizons of the sections of the latter series.

a. Deep-Well Sections.

(1) *Well-section at Wellington College.*—The specimens and measurements of the strata pierced in digging this well were preserved with great care. The sectional diagram (fig. 1) has been reprinted (with additional notes), with the courteous permission of the President and Council of the Geologists' Association, from vol. vi. of the 'Proceedings' of that Society. The grouping of the strata agrees substantially with that adopted by Prof. Prestwich many years ago†. A few supplementary notes, for which there is not sufficient space on the margin of the diagram, may be useful.

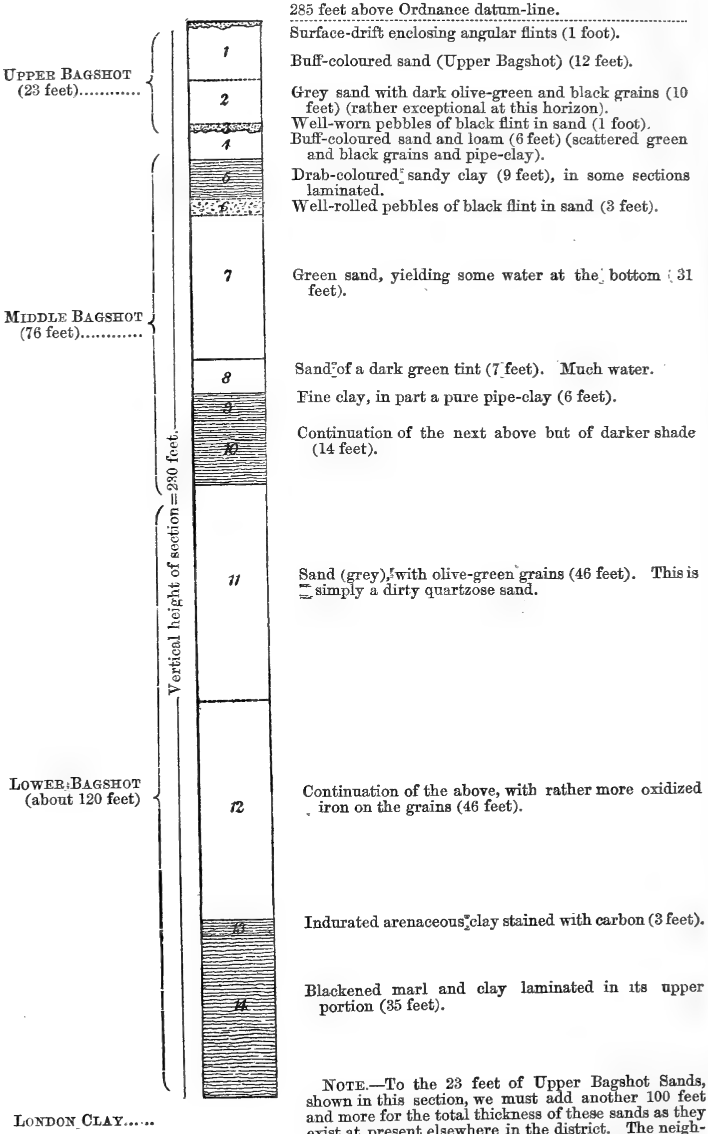
No. 2. This is a quartzose sand, stained with carbonaceous matter on the grains, with scarcely a trace of iron. The occurrence of this bed of dirty sand here is exceptional; this horizon is generally occupied by a bed of stiff yellow loam, almost a clay, which passes up into the yellow sands.

No. 5. This bed was worked for about twenty years in the neighbouring brick-field, and Wellington College was built with bricks for which it afforded the sole material.

* See Memoirs of the Geological Survey, vol. iv. pp. 329, 330, where the bed is described as "a bed of ferruginous sand without pipe-clay." The general outlines of Bagshot stratigraphy are given so fully in that work as to require no further description here. It has been generally assumed, but, I think, never *proved*, that this area of deposition was continuous with that of Hampshire through Bagshot times.

† Quart. Journ. Geol. Soc. vol. iii. *loc. cit.* As before intimated, however, I draw the upper boundary of the Middle Bagshots at a rather higher horizon.

Fig. 1.—*Vertical Section of Bagshot Strata disclosed in the Trial-boring for the Deep Well at Wellington College.* (Scale 40 feet =1 inch.)



NOTE.—To the 23 feet of Upper Bagshot Sands, shown in this section, we must add another 100 feet and more for the total thickness of these sands as they exist at present elsewhere in the district. The neighbouring hills, on which the Criminal Lunatic Asylum is situated, reach a height of 400 feet, and the continuation of the beds of the upper portion of this section beneath those hills is proved in numerous well-sections in the village of Crowthorne. We must have, therefore, a thickness of about 140 feet of Upper Bagshot Sands preserved in this neighbourhood.

No. 6. The rapid thinning-out of this pebble-bed was proved two years ago in an excavation made for a rain-water tank for the College Laundry. It was only 1½ feet thick there. In the neighbouring railway-cutting it has dwindled to a mere layer of pebbles.

No. 8. Small fragments of shells occur in this bed, which occupies the same horizon as that in which very complete specimens of *Cardita* &c. were found last year, in the well at Yateley Green, described below.

No. 9. The uppermost 6 inches of this bed show the green sand of the bed above, coarsely mingled with the clay; the next three feet consist of *pure pipe-clay*. Then, for about three feet, the clay is distinctly laminated and coloured with carbonaceous matter.

No. 10. This is a very homogeneous clay-bed, much stained with carbonaceous matter.

No. 12. This bed is slightly more loamy than No. 11. The specimens preserved have assumed a somewhat browner tint, as the result of oxidation during the last 25 years, from the presence of more iron in the material which coats the grains. The specimens of these two beds (11 & 12) have precisely the character assumed by the grey and greenish sands after long exposure to atmospheric oxygen.

No. 13. The clay of this bed is exactly like that of No. 10.

No. 14. The uppermost 25 feet of this bed are strongly laminated; the remaining 10 feet pierced have more the character of London Clay than of anything else. Here, then, we seem to find a *passage of the London Clay into the Bagshot Sands*.

(2) *Farnborough Deep Well.*—At the southern end of the parish, a new well was sunk last year by Messrs. Tilly and Sons for the District Waterworks. From the information furnished to me, and from inspection of the works, I have constructed the following section. The elevation of the mouth of the well above O.D. level is 250 feet.

		ft.	in.
	1. Gravel (mixture of pebbles and subangular flints) of later drift	7	0
Upper Bagshot, 128½ ft.	2. Yellow loamy sand	33	0
	3. Yellow sand, yielding water	33	0
	4. Yellow loam	8	0
	5. Grey loam	12	0
	6. Grey sand, yielding water	29	0
	7. White-grey sand, yielding water	13	6
Middle Bagshot, 31¼ ft.	8. Strong brown clay, pebbles at the top	0	9
	9. Green loam	17	0
	10. Hard gravel, pebbles	3	6
	11. Green loam and pebbles	10	0
Lower Bagshot, 62 ft.	12. Green loam and sand	22	0
	13. Green sand yielding water	22	0
	14. Green sand with thin layers of clay	3	0
	15. Strong green loam	12	0
	16. Green sand and water	3	0
	17. London Clay penetrated to	31	0

I am greatly indebted to Mr. Whitaker for additional notes made from examination of the specimens, and his grouping is here followed.

(3) *Mytchett Place, Frimley.*—An interesting section was obtained here about three years ago, particulars of which were furnished to me by the engineer engaged in making the trial-boring, Mr. Eggar, of Gower Street. Some specimens were preserved by the proprietor, J. G. Murray, Esq., who has courteously given me every facility for investigation of the matter. The following was taken from the coloured diagrams and measurements in possession of Mr. Eggar:—

Site 250 feet above O.D. level.

	ft.	in.		
1. White sand	to 53	0	Upper B., 65 ft.	Total of Bagshot Sands 195 feet.
2. Loamy sand..................	to 65	0		
3. Light green sand............	to 67	0	Middle B., 28 ft.	
4. Dark green sand	to 93	0		
5. Light green sharp sand ...	to 180	0	Lower B., 102 ft.	
6. Light green and sharp sand, "with shells," &c. ...	to 195	0		
7. Blue clay, with smooth pebbles	to 228	0	London Clay, 67 feet (?).	
8. Green loamy sand	to 230	0		
9. Blue clay with pebbles ...	to 234	0		
10. Blue clay	to 245	0		
11. Dark green sand and clay.	to 262	0		
12. Dark green sand without clay...........................	to 285	0	Reading Beds (?) 68 feet.	
13. Brown sand, marl, and clay	to 308	0		
14. Very fine sharp sand	to 330	0		

At this depth the tubes gave way in the "fine sharp sand," and the boring was abandoned. The few specimens preserved are from the last four of the above beds, and afford ambiguous evidence.

One or two remarks, based on a comparison of the deep-well sections just described, are called for here. (i) There is in all of them a general agreement (with difference in details) of the character of the strata of the three several divisions of the Bagshot Series. (ii) There is an absence of all record of pebble-beds in the Lower Bagshot. (iii) The Lower Bagshot beds are, in all the sections, characterized by the predominance of quartz-sand, coloured green and grey by the presence of organic matter of vegetable origin. (iv) There is an absence of any record of seams of pipe-clay, which are met with frequently in beds of the Middle Division (*cf.* fig. 1 and notes); and the comparative richness in clay-beds of the Middle Division distinguishes it from the Lower Division. It is of importance to note these characteristics of the Lower Sands in sections where the order of superposition (as in those just described) is as certain as anything can be.

b. Sections in which only portions of the Bagshot Series are exposed.

1. *Railway-cuttings at Wellington College Station.*—In the interpretation of the sections exposed in the two cuttings at this spot, one

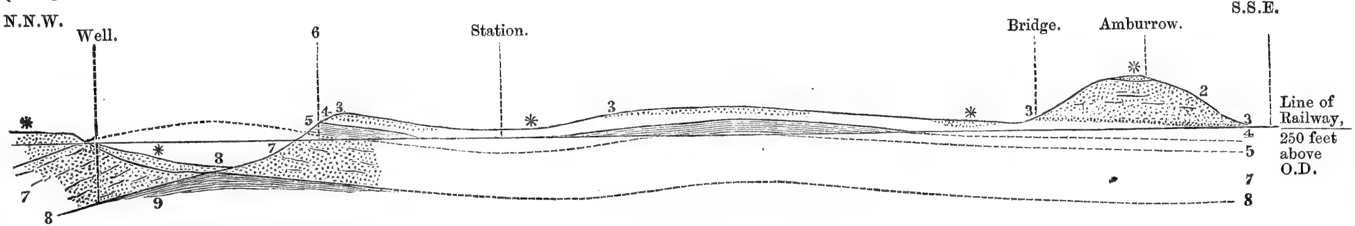
to the north, the other to the south of the station, I am compelled to differ somewhat from that which has been given to them in a paper by Mr. Monckton lately published *. The upper pebble-bed, north of the station, has been overlooked. The beds of the cutting to the north of the station are represented as passing, with a southerly dip, under the beds exposed in the cutting to the south of the station. This, however, would give to the Middle Bagshot series a much greater thickness than they are found to have in any known section in this district. At the northern end of the northernmost of the two cuttings nearly the whole of the Middle series is exposed; the sequence of the beds and their several thicknesses (except that of the lowest clay-bed, which is only exposed at the bottom of the valley to the north) correspond with the sequence and thicknesses of the beds (Nos. 3–9) in the well-section (fig. 1). Mr. Monckton, in the paper just referred to, has stated that the thickness of the beds of green sand (E. p. 350, *loc. cit.*) is not shown; yet I have been able to measure it, and find it to correspond very nearly with that of the beds of precisely the same character (Nos. 7, 8) in fig. 1. He has also stated that in the cutting to the north of the station the beds are "brought into the cutting by a fall of the line." Having taken observations with a spirit-level all along the cutting, I am unable to verify the statement, and the "fall" here referred to seems to be unknown to the plate-layers employed on that part of the line.

In the cutting to the south of the station, only the beds Nos. 3–5 of fig. 1 are exposed. The clay-bed of the northern cutting passes under the station, and comes up again in the southern cutting, rolling over to form a slight anticline, as we proceed south, until it again disappears near the bridge, about half a mile to the south of the station. The sequence, character, and thickness of the beds are the same as in the northern cutting, except that the green sand (No. 7) is not exposed. The upper pebble-bed occurs in precisely the same position, and its identity with the bed No. 3 of fig. 1 has been directly proved, within the last two years, by the deep trench made for the new main sewer of the College, the bed of well-rolled flint-pebbles imbedded in a stiff loam having been exposed continuously from the railway-cutting right up to the College, a distance of nearly half a mile. The facts furnished by this section will be best understood by reference to the accompanying diagram (fig. 2). At and immediately about the station the pebble-bed (No. 3) appears to have been much attenuated, and to have been reconstructed as later drift, the pebbles being mingled with a few angular discoloured fragments of flint, such as form the chief ingredient of the later drift-gravels of the higher parts of the country. In the cuttings, however, both to the north and to the south of the station, the original Bagshot pebble-bed has remained intact. On account of the water-logged condition of the beds in this syncline, piles had to be driven to get a foundation for the station.

To the east of the railway, in the brick-field, and in the arable land

* Quart. Journ. Geol. Soc. vol. xxxix. p. 351.

Fig. 2.—*Section on South-eastern Railway, near Wellington College, Berks.*
(Length of Section, a little over 1 mile. Scale, 1 : 10; *horizontal*, 6 inches=1 mile, or 1 inch=880 feet; *vertical*, 1 inch=88 feet.)



References as in fig. 1.

2. Buff-coloured Upper Bagshot sands, reaching a height of 332 feet in the hill.
3. Bagshot Upper Pebble-bed, of frequent occurrence at this horizon.
4. Sandy Loam, passing locally into a clean sharp sand, much eroded in places, with thin seams of pipe-clay.
6. Lower pebbly horizon: here a mere layer of pebbles, 3 feet in well-section (fig. 1) of pebbles in sand (very local).

7., 8. Green sands of the Bracklesham Beds (Middle Bagshot), thickness here corresponding with the thickness in the well-section.
9. Lower Clay-bed of the Bracklesham Series, always present, but varying much in thickness.

* Later surface-drift, consisting, where it rests upon bed No. 4, of sand, many flint pebbles, and a few angular flint fragments; it is therefore the pebble-bed (No. 3) reconstructed by later drift-action.

immediately to the south of it the pebble-bed, intermingled with a few subangular fragments of the later drift, and probably somewhat reconstructed, is exposed at the surface, many of the pebbles being very large (4 to 6 inches in length). A little further south, at the College Pig Farm, the same bed was found intact, with a thickness of about 3 feet, so recently as last year, and worked for gravel. The bed there was simply a mass of rounded flint-pebbles imbedded in sand. On the west of the railway, to the south of Amburrow Hill, it has been again exposed in excavations recently made for building-purposes, and it is well exposed in the grounds of Sandhurst Lodge, the residence W. J. Farrer, Esq., F.G.S.

The height above O.D. level of the Middle Bagshots at the Wellington well-section will be seen from an inspection of fig. 1. The upper pebble-bed, for example (no. 3), is there found at a height of about 260 feet; and in the sections just described its height ranges (owing to dip) from about that height to 250 feet. These observations as to altitudes, it may be remarked, are taken (as are all the heights mentioned in this paper) from the Ordnance Map of the district, constructed on the scale of 6 inches to the mile.

2. *Wellington College Lakes.*—The 250 feet contour-line passes along the margin of the lowermost of these lakes, which have been formed by simply damming up the natural drainage of the valley; and the same line passes close to the railway-station. Last year an extensive excavation for the new swimming-basin exposed the pebble-bed just below the level of the water, at a height above O.D. level of 250 feet. Below this (which was of the same character as is exhibited by it in the railway-cutting to the north of the station) there was exposed from six to eight feet of yellow loam; and beneath this again the green clayey bed is exposed in the open water-course by which the lake may be drained. There is no difficulty in identifying the beds here exposed with those of Nos. 3, 4, and 5 of figs. 1, 2; and the continuity of the green loamy sand bed between these two places has been proved in recent excavations. On both sides of the lake a stiff yellow loam (almost, in fact, a clay) occurs above the pebble-bed (No. 3), as it commonly does at the base of the Upper Bagshots above the pebbles (*cf. ante*).

3. *York Town and Camberley.*—Here some extensive drainage-works have been constructed during the last two years. The main sewer follows the turnpike road. It commences where the road passes over the shoulder of the Obelisk Hill, at a height of some 320 feet. As the excavation descended the hill, it exposed nothing but the usual buff-yellow sands of the Upper Bagshots, until the altitude of about 260 feet was reached. At this level the sands were found passing down into the usual yellow clayey bed, and beneath this a bed of flint pebbles was passed through. Below these pebbles a yellow loamy sand was passed through till the level of 247 feet was reached, when this passed into a green bed of clay and sand, of about ten feet in thickness. Below this the excavation was continued in loose green sand, the bottom of which was not reached.

The correspondence in thicknesses and altitudes of the beds here

exposed with the same sequence of beds shown three miles off at Wellington College (figs. 1, 2) is remarkable.

4. *Yateley Green.*—A well, eighteen feet in depth, has been lately sunk here at the residence of the Misses Ridley. This well is entirely in the thick middle green sands of the Middle Bagshots. Nothing but green sand was passed through, of the same character as that of the beds Nos. 7 and 8 in figs. 1 and 2, and the water-bearing horizon at the base of these green sands was reached. There was a great "find" here of Middle Bagshot fossils of Bracklesham age, which Prof. Prestwich has pronounced to be the most perfect forms he has yet seen from the Bagshot beds of the London Basin. They include very well-preserved specimens of *Cardita planicosta* (in great numbers), *Ostrea flabellula*, *Natica ambulacra*, and a fish-vertebra, probably of the genus *Otodus*.

The height of the beds here exposed corresponds almost to a foot with the height of the same beds in the College well-section (fig. 1).

5. *Farnborough.*—A very good section of the buff-yellow Upper Bagshot Sands is shown in the cutting of the main line of the S.W. Railway to the east of the station, and is continued in the hill above, where these sands have been lately exposed by an excavation for the crypt of the Imperial Mausoleum just erected on the summit of the hill. The base of the upper division is not exposed. In the excavation for the crypt, the sand was found to be washed almost to a clean white sand, and partly indurated near the surface, the depth of the sand of this character increasing as the hill was descended. This I attribute merely to the solvent action of the humus-acids furnished to the rain-water as it percolated through the sand having dissolved out the iron as neutral soluble salts, the iron being afterwards precipitated by oxidation when the water was thrown out by springs at lower horizons. This process may still be observed in numerous streams in the Bagshot country. Masses of sand more than usually ferruginous were met with here, as in other sections in the Upper Sands; and in some of these casts of shells were found, including one of *Panopæa intermedia*, a species figured in Dixon's 'Geology of Sussex' as belonging to the Bognor Sands. The height of this hill is 285 feet above O.D. level, and from 70 to 80 feet of strata are exposed down to the level of the line.

At Farnborough Rectory, a quarter of a mile to the south (250 feet above O.D.), a well dug last year reached the clay at the base of the Upper Bagshot at a depth of 46 feet.

6. *Aldershot.*—The mass of Upper Bagshot mapped by the Survey east of the South Camp is known as Thorn Hill (400 feet high). A sand-pit on the southern face of this hill exposes true Upper Sands, and shows the correctness of the map here. At 350 feet above O.D. level the true Bagshot Pebble-bed is seen cropping out between this hill and Cambridge Hospital, and resting upon a yellow and brown loam with seams of pipe-clay. West of the hospital, at the same level, the Pebble-bed is three feet thick, where it caps the escarpment; it dips to the *north*, conformably with the underlying bed of brown and yellow loam. A little further

west a very marly bed, with many pipe-clay laminæ, is seen in a road-cutting dipping 2°·5 north; below this is a more sandy bed with numerous green grains.

Crossing over to the south side of the town, a good section, opened in the last two or three years, is met with in the brickyard between the reservoir on the hill and the station. Here a brown and yellow loam, well stratified, with numerous seams of pipe-clay (some of them several inches in thickness), corresponding in character with that which underlies the pebble-bed on the northern side of the town, is seen with a dip of 2° *south*, with a layer of indurated ironstone at the bottom, lying upon an eroded surface of London Clay, which is now here worked extensively for bricks, and is therefore seen in good fresh sections. From its position and character I regard this loamy bed with its subordinated seams of pipe-clay and green grains as the loamy bed No. 4 of figs. 1 and 2 developed in somewhat larger proportions on this southern side of the Bagshot area.

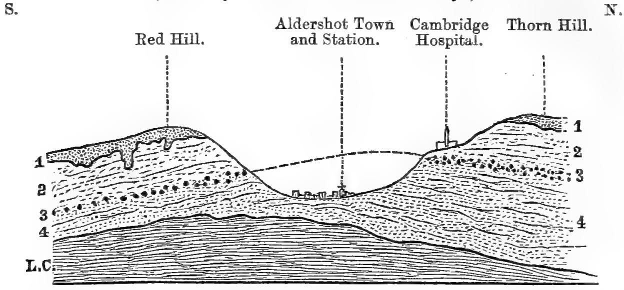
A similar loamy bed is exposed in the cutting at the foot of Redan Hill, which is penetrated by a short tunnel a short distance east of the station. Along the top of this bed of loam I found perfectly rounded flint pebbles (some of large size) imbedded in a stiff loam; and above this line of pebbles buff-yellow sands are exposed for about fifty feet vertical. The pebble-bed here and the sands above appear to dip to the east; but that the true dip is a good deal to the south of east is indicated by the occurrence of the line of pebbles at a level some 15 feet lower in a well-section in the cemetery to the south-east of the cutting.

I got hold of a well-digger named Lynch, who has been engaged in the digging of a good many wells (several of them being deep) in and about Aldershot, and took him to look at the exposures of the loamy bed, pointing out to him its characteristics. He assured me that the same kind of "loamy sand" was invariably met with before passing into the "blue clay" in all the wells of which he had any knowledge, and the indurated ironstone band was generally present at its base. From the depth he gave me of the surface of the "blue clay" in several wells, the Bagshot Sands evidently lie here unconformably against London Clay; and we have seen above that in one section at Aldershot (that in the brickyard) there are good reasons for regarding the bed seen lying immediately upon the eroded London Clay as the uppermost bed of the Middle Bagshot. Redan Hill, though mapped as Lower, must be regarded, I think, in the face of the above evidence, as *Upper* Bagshot.

The accompanying sectional diagram (fig. 3) has been constructed from the evidence here given.

6*a*. *Cæsar's Camp, Aldershot.*—The Middle Bagshot green sands are exposed in a section at the rifle-butts at the foot of the northern escarpment of this hill at the height of about 350 feet. This gives us more than 200 feet as the thickness of the Upper Sands in this hill and Beacon Hill, which are 600 feet high. Mottled clay, which it would be difficult to regard as anything else

Fig. 3.—*Section across the Valley of Aldershot Town.*
(Greatly exaggerated vertically.)



1. Drift gravel, chiefly of subangular discoloured flint lying on a deeply eroded surface of
2. Upper Bagshot Sands, with predominant colour buff-yellow.
3. Bed of well-rounded flint pebbles.
4. Yellow and brown loam and loamy sand, with numerous layers of pipe-clay, occasionally several inches in thickness.

L.C. London Clay. Occasional flint pebbles and shark's teeth are met with in the clay-pits in the neighbouring brick-fields.

than reconstructed clay of the Reading Beds, is present here in a considerable mass several feet in thickness, intercalated with the green sands. Above the rifle-butts a section of the Upper Sands shows a dip of 2° south; and in a section on the southern side of the hill I measured a dip of 8° south. The hill-cap also slopes about 2° to the south. The Middle Bagshot beds exposed at the rifle-butts pass not only through Cæsar's Camp, but through Hungry Hill also, which has somehow got mapped as *Lower* Bagshot. This hill is 550 feet high, the sections about its upper part, down to about 350 feet, show Upper Bagshot Sands like those of the upper 200 feet of Cæsar's Camp, and springs come out at about 350 feet level. At about this level, on the southern slope of Hungry Hill, in the village of Upper Hale, the water-bearing horizon at the base of the Upper Sands is proved in two wells, one of which begins at a height of about 450 feet and is 114 feet deep, while the other begins at a height of 400 feet or so and is 56 feet deep. This information was given me by the man who was engaged in digging them. A little way further down the hill the "blue clay" was penetrated at a depth of about 25 feet. These facts do not harmonize with the details of fig. 89, p. 376 of the Survey Memoir, and they are still more discordant with the mapping, which represents the Middle Bagshot beds as cropping out on the eastern flank of Cæsar's Camp, where a drift-clay deposit lies upon the slope of the hill; it is to be seen at the rifle-butt filling an eroded hollow in the Middle Bagshot beds, which are as nearly as possible horizontal, instead of lying at a high angle, as the mapping would require. This clay is as unstratified as any Boulder-clay, and bricks were made from it rather more than 20 years ago at a height

of about 500 feet. In the wells mentioned on the southern slope of Hungry Hill nothing but buff-yellow sand, occasionally more deeply stained with oxide of iron, was met with, and the water-bearing stratum was described to me as a "stiff yellow loam."

From the facts just mentioned it would appear that beds high up in the Bagshot Series rest against the London Clay in these hills.

7. *Valley north of Wellington College Station* (comp. fig. 2).—Turning to the geological map, we find the northern boundary of the Middle Bagshot drawn along this valley; but there are reasons for doubting the correctness of this delimitation, and for regarding the beds on the north side of this valley as a repetition of the beds of the Middle Division exposed on the south side of it, though they are obscured by a considerable accumulation of drift on the north side. The facts are as follows:—

(1) The Clay-bed (No. 9) is reached in the valley at a higher level than the bottom of the valley This position of the clay is represented in fig. 2.

(2) A little further to the west, where the old Roman road known as the Devil's Highway crosses the highroad to Wokingham, a well has been recently dug to a depth of 38 feet. The mouth of this well is about 240 feet above O.D., and therefore about 10 feet lower than the uppermost limit of the green-sand beds (No. 7 of figs. 1 and 2) exposed at the northern end of the cutting. Making allowance for the decoloration of the upper portion of the green sand in this well-section by the action of oxygenated rain-water, there is a striking correspondence in the sands pierced by this well and the sands (Nos. 7 and 8 of fig. 2) which crop out on the opposite side of the valley; the green staining of the sand increased in intensity with the depth of the well; lignite in a fragmentary state abounded in it, especially in the lower portion; and at the bottom of the well laminated clay was found, like that of bed No. 9 in figs 1 and 2.

(3) In the shallow cuttings of the railway, both north and south of the Nine-mile Ride, the bed exposed agrees in character with the bed No. 4 in fig. 2, and upon it a pebble-bed is found to rest (especially well seen in an old ballast-pit adjoining the railway), as the pebble-bed No. 3 does in the section represented in fig. 2. The pebble-bed at this spot is about 210 feet above O.D level.

(4) The brook-section west of the railway (though obscured very much by peat-deposits) shows here and there clay similar to that found in the bed No. 5 of fig. 2, at a height of 200 feet.

(5) Very near to this, an extensive lake-excavation, recently made, was chiefly in a loamy sand, reaching a laminated and green bed at its deepest part, at levels corresponding with those just described (3, 4).

(6) Half a mile to the west a hill in the midst of the pine-woods has been excavated for rifle-targets at about 210 feet above O.D. Loamy sands, with seams of pipe-clay, are exposed here with a *dip of nearly 5° to the north.*

(7) A third of a mile to the west of the rifle-range on the north

slope of Upwick's Hill a clay-bed with intercalated layers of green sand is exposed in a clay-pit on the 250 feet contour-line. This agrees in character with the bed No. 5 (fig. 2). Above it is a loamy bed stained green, as the bed No. 4 is occasionally, where, when the contour of the country was somewhat different, it may have underlain for a long time a marshy deposit. Some 20 or 30 feet below this, a light-coloured clay, which resembles very closely the lower clay of the Middle Division (Nos. 9 and 10), is extensively worked for bricks in Mr. Walter's brickyards. This I am now disposed (after examining the evidence more closely) to regard as belonging to that horizon, even though the sandy beds exposed immediately above it in the same section are not green, the green colour having been probably changed to a rusty brown by recent oxidation.

8. *Road-section ¾-mile north of Wellington College.*—The new road to Wokingham crosses here the same line of valley (7) as that which the railway crosses north of the station.

The slight anticlinal arrangement of the Middle Bagshot beds (Nos. 4, 5, 7, figs. 1 and 2) is shown here more plainly. The overlying pebble-bed (No. 3) is found on both sides of the valley, and the beds Nos. 4 and 5 are well exposed in the road-cuttings on either side. The clay-bed (No. 9) appears low down the valley and is seen by the side of the ditch. Halfway between these two sections the bed No. 5 was worked near Clark's cottage for bricks about fifteen years ago.

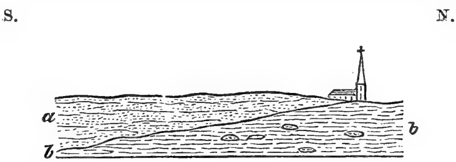
9. *Wokingham.*—On the map this town is represented as lying on an outlier of Lower Bagshot Sand (*i.* 4). This, however, admits of question, since the sands, wherever exposed or penetrated in the numerous wells (from 20 to 30 feet deep) in the town, are buff-yellow sands like those of the Upper Division. There is a section exposed on the South-western Railway, where the footpath crosses the line between the town and Tangleys. The beds exposed here consist of sand and light loam with thin layers of pipe-clay, and are more like the bed at the top of the Middle Division (No. 4, fig. 2) exposed in the railway-section at Wellington-College station, than anything else with which I am acquainted in the Bagshot Series. The height here is 200 feet, and the London Clay is met with about 4 feet below the line, while a little further down the valley to the west the Wokingham Town well * commences in the London Clay itself. The beds exposed in this cutting are horizontal in an east-and-west direction; but from the absence of good exposures on the northern slope of the cutting, it is impossible to say if there is any dip in a north-and-south direction. One or two thin lines of pebbles occur in this section, and upon the sands just described a bed of pebbles (cut through in places by later drift) is to be seen. Not far from this cutting the London Clay is worked in Mr. Churchman's brickyard, and there the buff-yellow sands of the hill-cap are seen filling the hollows of the eroded surface of the London Clay.

* Described by Prof. T. Rupert Jones, F.R.S., in the Geol. Mag. dec. ii. vol. vii. p. 421, &c.

At St. Paul's rectory two wells were dug a few years ago by my friend the Rev. J. T. Brown. Commencing at about the same level with both wells, which are only a few yards distant from one another, in one well 25 feet of buff-yellow sand was passed through, and then a copious supply of good water was obtained at the top of the London Clay; in the other a mere layer of yellow sand was passed through, when the "blue clay" was pierced and penetrated to a depth of 135 feet. This fact seems to admit of no other explanation than pronounced erosion of the London-Clay surface beneath the Bagshot Sands of the Wokingham outlier.

Just north of Wokingham station there is another exposure of Bagshot Sands, which agree in character with the loamy sands of the bed No. 4 of figs. 1 and 2, to which reference has been so often made. The sands are exposed just below St. Paul's church. Immediately to the north of the bridge over the railway, the London Clay with septarian nodules comes in at the bottom of the cutting, and rises as we advance northward along the cutting until the overlying sands disappear. Yet the stratification of both the Bagshot Sands and the London Clay is *horizontal*, as proved for the former in the section below the church, for the latter in Mr. Phillips's brickyard just below. Here, then, we have a case of the Bagshot Sands (whatever particular horizon they may occupy in the Bagshot Series) deposited against a denuded shelving shore of the London Clay, unless we assume the presence of a fault hading at a very low angle. This is more clearly expressed in the adjoining diagram (fig. 4).

Fig. 4.—*Section in Cutting north of Wokingham Station.*



a. Bagshot Sand. *b.* London Clay.

10. *Bracknell.*—Bracknell station (on the South-western Railway) is 250 feet above O.D. level. In the long cutting east of this station beds of the Middle and Upper Bagshot Sands are exposed.

	ft.
d. Buff-yellow sands	10–15
c. Bed of flint pebbles imbedded in sand	1
b. Yellow loamy sand	6
a. Dark black and green clay (exposed)	4

The lowest bed (*a*) here exposed gave much trouble in making the cutting. Being water-logged, it caused numerous "slips," so that rushes had to be planted along the bottoms of the cutting-slopes to give them security. The altitude of the pebble-bed at this spot is 260 feet, which agrees with the altitude of a massive

pebble-bed at Easthampstead church, about a mile to the south, and with that of the pebble-bed of the sections already described at Wellington-College station and at Camberley, as well as with that of the pebble-bed at the top of the Middle Bagshots exposed in the cuttings on the new line between Ascot and Bagshot *.

At the top of the Bracknell cutting flint-pebbles come in again in great force, the original bed having been, it would appear, reconstructed. I saw them again in great quantity, without observing a single angular fragment of flint among them, in a garden close by Bracknell church; and at Wick Hill, half a mile further to the north, they are seen lying upon yellow loamy sand, and filling up the hollows of its eroded surface to a depth of three feet, at an altitude of about 285 feet. I could find no evidence to indicate a southward dip in the strata hereabouts, and there is certainly none in the railway-cutting. Moreover, on the slope of Wick Hill a feebler pebble-bed is exposed in the ditch, a few feet only above the London Clay, agreeing in character and position with that exposed in the railway-cutting (*c*). There are clearly, therefore, *two* pebble-beds at Bracknell. That we have good reason for regarding them both as belonging to the Upper Division of the Bagshot series, I think I may claim to have shown, though these Bracknell beds are mapped as Lower Bagshot (*i*. 4).

General Conclusions.

By the evidence given in the preceding sections, I think some new light is thrown upon the physical history of the Bagshot strata of the London Basin.

1. We have succeeded in tracing pretty clearly the horizon of the Middle Bagshot strata and the base of the Upper Bagshot across nearly the whole of the country from Aldershot to Wokingham, a distance of about 13 miles.

2. While in the deep-well sections the order of superposition is clear, and the Lower Bagshot Sands of those sections are characterized by the great predominance of green sand, or sand coloured by amorphous matter of vegetable origin, we fail to find such sands along the northern and southern margins of the area.

3. A passage from London Clay into Lower Bagshot Sands seems pretty clear in the deep-well section at Wellington College, and may exist in the other deep-well sections; but in the sections described in this paper on the north and south there appears to be no such passage. On the other hand, both on the northern and southern margins higher members of the series than the Lower Bagshot are found lying in close proximity to the London Clay, evidence of unconformity being furnished in several of the sections.

4. The Bagshot strata, as a whole, do not lie in a synclinal curve, though a true synclinal arrangement prevails in the southern half of the region, which may perhaps be fitly termed the Farnborough Syncline.

* *Vide* Monckton, Quart. Journ. Geol. Soc. *loc. cit.*

The base of the Upper Bagshot, for example, is found at the respective altitudes of 350 feet at Aldershot, about 130 feet at Farnborough and Mytchett, 250 to 260 feet at Camberley and about Wellington College, and again about 260 feet at Bracknell. There must therefore have been earth-movements accompanied by alterations of level since the Bagshot strata were deposited, as if caused by lateral pressure acting in a north-and-south direction. Such movements may have been synchronous with the greater movement which produced the Isle-of-Wight anticline, and placed the whole Bagshot Series at a high angle of inclination along the north side of its axis. In the greater elevation of the Bagshot horizons at Aldershot, there seems to be some indication of an additional elevation of the line of the Hog's Back, and therefore probably of the Wealden anticline, after the Bagshot Strata of the London Basin were deposited.

5. The great thickness of the Lower Bagshot Sands in the deep-well sections, taken together with their passage downwards into the London Clay, their diminution in thickness southwards, and the apparent absence of them, in the sections described, along the northern and southern margins of the district, are good reasons for believing that previous to the deposition of the Lower Bagshot Strata the London Clay was thrown into a slight syncline, and suffered a considerable amount of denudation during Bagshot times, both on the northern and southern sides of the area; a strong case for the overlap of the Upper Bagshot Sands seems thus to be made out.

6. This last conclusion seems to be borne out by a comparison of some ascertained thicknesses of the London Clay itself.

(*a*) At Wokingham this has lately been proved to be only about 270 feet. In the well for the Wokingham District waterworks, of which a complete section has been recorded by Prof. Rupert Jones *, the boring commenced in the London Clay and passed through 263 feet of that formation; and the Bagshot Sands rest upon the London Clay near by, at a level only a few feet above the mouth of the well.

(*b*) In the Wellington-College well, the Chalk is said to have been reached at about 650 feet. Deducting from this rather more than 200 feet of Bagshot Strata (*cf.* fig. 1), we have over 400 feet for the vertical range of the London Clay and the Reading beds.

(*c*) Quite recently the Chalk has been reached at Brookwood, as I am informed by Mr. Thomas Tilly, of 15 Walbrook, at a depth of 640 feet from the surface. This gives us over 400 feet for the thickness of the London Clay at this spot.

(*d*) At Aldershot the thickness of the London Clay was proved a few years ago, in the Aldershot town well, to be 120 feet. The mouth of this well, which begins in London Clay, is 250 feet above O.D. level, and the Bagshot Sands are seen resting upon the London Clay at a level not much more than 50 feet higher, so that the thick-

* Geol. Mag. dec. ii. vol vii. p. 421

ness of the London Clay beneath Aldershot may be estimated at less than 200 feet.

7. A comparison of the sections described in this paper shows that at one horizon (the base of the Lower Bagshots) the beds of flint pebbles are far more widely distributed than at any other horizon. Whether these pebbles are fragments of flint worn by the rolling of a tidal surf and derived immediately from the denudation of the Chalk, or were first imbedded in the Reading beds and the basement-bed of the London Clay, and supplied to the Bagshot Strata by the denudation of those portions of the Lower London Tertiaries which became more generally exposed to denuding agencies at the incoming of the period marked by the Upper Bagshot Sands, the Bagshot sea must in either case have had access to older formations; and this could hardly happen without unconformity *. I attach great weight to the evidence afforded by the wide range of the pebble-bed at the base of the Upper Bagshot Sands, as showing at that stage a much greater extension of the area occupied by marine waters, and the consequent overlap of the Upper Sands; and this is borne out by the numerous casts of diminutive forms of a saltwater fauna † (such as we should find in a shallow sandy estuary open to the sea) which are met with in the buff-yellow sands of the Upper Bagshot, at horizons not far above the pebble-bed at the base. This cumulative evidence seems to show that at the incoming of Upper Bagshot times extensive denudation of the Reading beds and the base of the London Clay was going on; and this view is borne out by the appearance of mottled clays intercalated with the green sands at the foot of Cæsar's Camp near Aldershot, which has been already mentioned.

Further to the west, along the south side of the valley of the Kennet, there is strong evidence of unconformity. Sections are mentioned in the memoir ‡ where loamy sands with overlying pebble-beds (which agree in character more with the upper bed of the Middle Bagshot and the overlying pebble-bed of the sections described in this paper than with anything we know of in beds of undoubted Lower Bagshot age) rest upon the London Clay within a few feet only of its basement-bed. In one section these loamy Bagshot Sands are said to rest immediately upon the London Clay basement-bed, and in another to overlap even this and to rest immediately upon the Chalk.

The difficulty in the way of the theory suggested in this paper, arising from the presence of marine shells (*e. g.* at Yateley) in the Middle Bagshot beds, may be perhaps removed if we recollect that (1) they occur very locally; (2) they are, as a rule, much broken, worn, and even comminuted; (3) they appear to be confined to the coarser sediments of the Middle Bagshot beds. Such results might

* This was pointed out by Mr. Whitaker when this paper was discussed at the Society's Meeting.

† Comp. Monckton, *loc. cit.*

‡ Geological Survey Memoirs, vol. iv. pp. 178, 179.

easily follow from occasional and local intrusions of the sea (perhaps at unusually high tides), owing to the shifting nature of the land-barriers which are formed and removed from time to time at the sea-margin of a delta.

Discussion.

Prof. Prestwich, while admitting some of the facts recorded in the paper, could not agree with the Author in some of his conclusions drawn from those facts. The variations in thickness of the London Clay were no proof of actual unconformity. His many deep-well sections were, he thought, of much interest. At the time he had himself studied the country, the district was a wilderness, and there was only one well-section into the Chalk in the district. He did not attach the same importance to the minute subdivision of the Bagshot beds which the Author did. He did not think sufficient allowance had been made for local variations in the divisions of such beds as the Bagshot series.

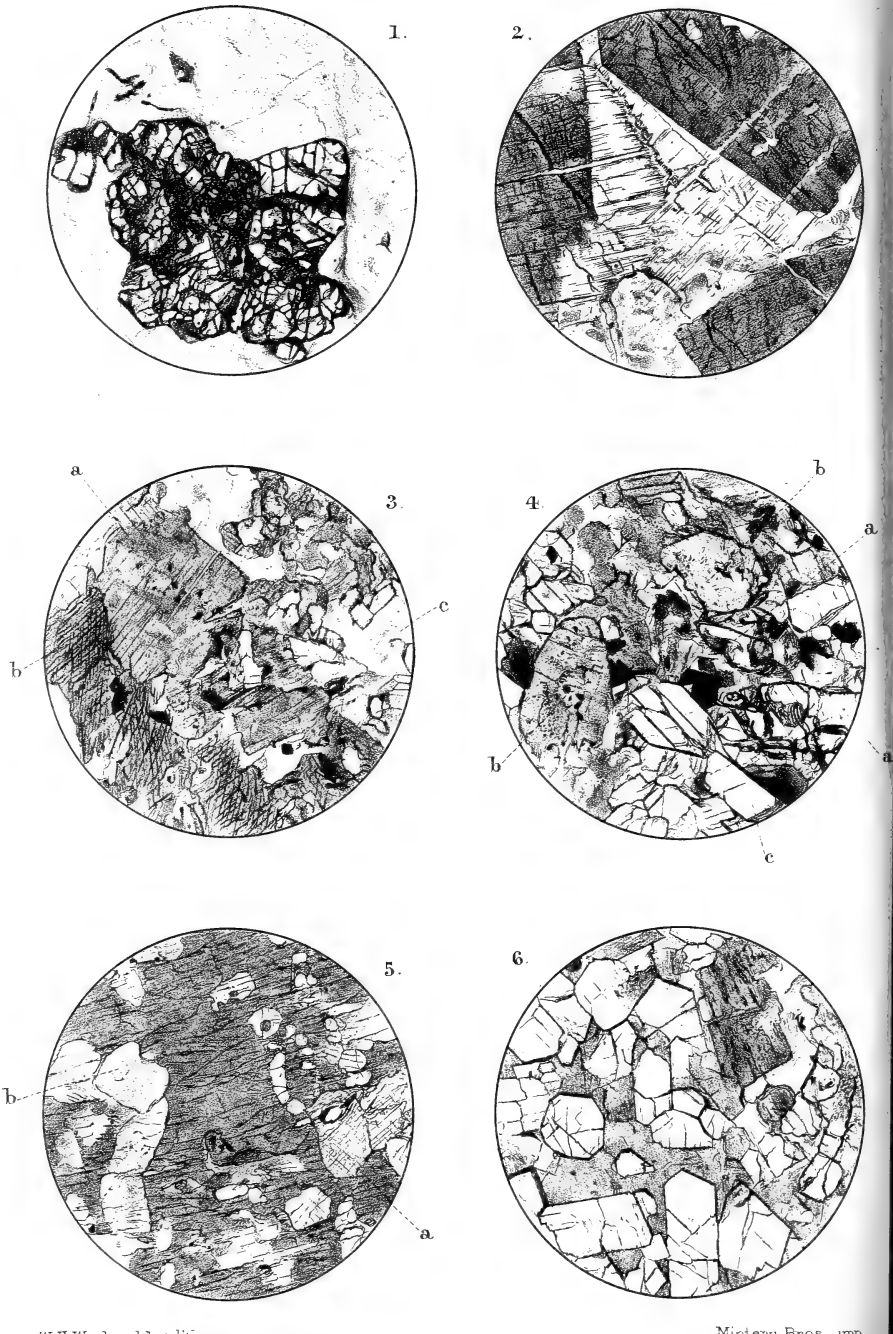
Prof. Rupert Jones thought, with the Author, that the pebble-beds marked the lapse of considerable intervals of time. He thought that the variations in the thickness of the London Clay were very interesting; but the persistence of the Woolwich Beds showed that the flexure of the strata took place after the deposition of the Bagshots. He had seen an apparent unconformity between the Bagshots and the London Clay at Bracknell.

Mr. Whitaker stated that when the geological map of the district was made by his colleagues very few sections existed. He thought that the pebble-beds were of importance, though not persistent. Mr. Polwhele trusted rather to the green bed than to the pebble-beds as his guide in mapping the Middle Bagshot. The occurrence of pebble-beds composed entirely of Chalk-flints was a proof of the existence of an unconformity somewhere, as they showed that the sea of the period must have reached the Chalk. He had pointed out the likelihood of this having occurred in the far west of the London Basin.

Mr. Monckton entirely disagreed with the interpretation of the sections by the Author. He regarded well-sections with the very greatest suspicion. He considered the green sand the type of the Middle Bagshot. He agreed with Mr. Whitaker that the Author had confused pebble-beds on different horizons, some near the top of the Middle and others in the Lower Bagshots. He thought the sands and pebble-beds of the Lower Bagshot were always clearly distinguishable from those of the Upper Bagshot.

The Author admitted that pebble-beds alone did not define horizons, and he had not referred to them in this way except where the sequence of beds above and below them was undoubtedly clear. He had endeavoured in the paper to explain the remarkable persistence of that which occurs at the base of the Upper Bagshot sands,

and the conditions indicated by it and its position. The previous speakers had overlooked the fact that the Lower Sands, when near the surface, were only the dirty green sands of the deeper well-sections, cleaned from carbonaceous matter by the action of oxygenated water, delta-conditions characterizing both the Middle and Lower series. The horizon of the pebble-beds at Bracknell was very clear, the evidence of this being given in the paper. In the section near Ash mentioned by Mr. Monckton the northward dip of the Lower Bagshots corresponded with the northern dip of the small anticlinal at Aldershot; and a comparison of the two sections seemed to afford further proof of the pre-Bagshot erosion of the London Clay. He regarded the whole evidence as pointing to the partial formation of the present London-Clay syncline and to considerable denudation before the deposition of the Bagshot beds.



W. H. Wesley del. et lith.

Mintern Bros. imp.

CUMBRIAN AND WELSH PICRITES.

37. *On the so-called* Diorite *of* Little Knott (Cumberland), *with further remarks on the* Occurrence *of* Picrites *in* Wales.

By Professor T. G. Bonney, D.Sc., LL.D., F.R.S., Pres. G.S., Fellow of St. John's College, Cambridge. (Read May 27, 1885.)

[Plate XVI.]

In my second note * on the hornblende-picrite boulders which are scattered over the neighbourhood of Ty Croes, Anglesey, I briefly noticed a similar rock which occurs *in situ* at Little Knott in the Lake District, and has been described by the late Mr. Clifton Ward as an exceptional variety of diorite. In the spring of last year I was enabled to visit this district, and had the advantage of the company of Mr. J. Postlethwaite of Keswick, whose local knowledge was of great assistance to me. Little Knott is a slight prominence or shoulder on the crest of Long Side, a spur from the main mass of Skiddaw, where the former begins to fall more sharply down to the lowlands on the north. The picrite is represented on the six-inch map of the Geological Survey as an elongated dyke-like mass, running nearly E. and W. for about 650 yards, and generally about 40 yards wide, the outcrop of which extends from Little Knott across a ravine to a point at about the same elevation on the opposite ridge. The boundary, however, is inferential in a part of this area, as the rock is by no means continuously exposed, no small portion being covered with turf.

Long Side consists of Skiddaw Slate; at one locality on its western slope Graptolites are not rare, and here Mr. Postlethwaite on the occasion of our visit discovered a *Lingula*. At Little Knott itself the picrite mass, being about its usual width, is bounded on either side by a low outcrop of indurated Skiddaw Slate. From this part of the crest the picrite can be traced eastwards down the steep slope; an irregularly projecting mass, traversed by occasional joints, and thus divided into large blocks, giving to the greater prominences quite a grandiose aspect. It follows the line of a slight depression and is ultimately covered up by the turf. The burn at the bottom of the glen runs over a mass of boulders. On the opposite hillside no rock was visible above the turf until we reached about the level of Little Knott, where, on the brow of the ridge, is a group of huge blocks. I could not satisfy myself that any of these were certainly *in situ*, though the live rock must be close at hand. Mr. Ward, I find, regarded them as boulders. The largest block is about 18 feet long, 8 feet wide, and 7 feet high: it rests on Skiddaw Slate, which has a baked aspect and appears to be *in situ*. A short distance to the south, among indurated Skiddaw Slate, is an outcrop which Mr. Ward

* Quart. Journ. Geol. Soc. vol. xxxix. p. 254. I may take this opportunity of correcting a misprint: on p. 255, line 8, for *milky* read *silky*.

connects with the mass on Little Knott. This very probably is correct, but the rock appeared to me limited in area. It is fine-grained and not at all characteristic. It is, however, possible that I may have overlooked some small connecting outcrops lower down the hillside.

The rock, as seems not seldom to be the case with picrites and the more basic olivine-diabases, varies greatly in character. At the first outcrop on Little Knott the dominant rock (No. I.) is fine-grained, not porphyritic, and not at all like that of the Anglesey boulders, resembling a dioritic rock rich in hornblende and poor in felspar. There is also, near the western end of the area, on its northern side, an outcrop of rock (presumably connected with the main mass and close to the altered Skiddaw Slate) which is very compact, of a dull grey colour, more like a felstone. Then a short distance further east, the ordinary, rather fine-grained, dull green variety (No. II.) passes gradually in the space of about a yard into a mottled pinkish-grey and dull green rock, like an ordinary syenite or diorite (No. III.). Further down the eastern slope of the hill, about the central part of the exposure, the rock becomes coarser, crystals of hornblende about ·2 to ·3 inch across, with the characteristic dull green serpentinous enclosures, being abundant (No. IV.). Here and there the rock becomes still coarser, the hornblende crystals being ·4 or perhaps even ·5 inch across, but I did not find any larger than this (No. V.). In one part the bigger crystals are rather crowded together and tend to occur in veinlike bands. The coarser varieties much resemble the rock of the Anglesey boulders, in which, however, the hornblende crystals are often slightly larger. The rock of the boulders on the crest of the opposite (eastern) ridge corresponds with the medium variety (No. IV.).

I have had slides prepared for microscopic examination from each of the above-mentioned varieties of the Little-Knott rock.

No. I. A granular rock, composed of dark hornblende with grains of a paler green mineral; the former about ·1 inch in diameter. The following minerals are visible under the microscope:—(1) hornblende, mostly in irregularly formed crystals interrupted by somewhat rounded enclosures. Colour generally a rich brown, strongly dichroic. Cleavage well-marked. This passes sometimes rather abruptly, as described on a former occasion, into a pale green rather fibrous variety, smaller flakes of which are scattered about the slide. The enclosures, above described, are mostly occupied by secondary products, in some cases serpentinous, but occasionally a crystal of felspar is included. In the slide, intercrystallized with the smaller and more altered hornblende, is a fair amount of felspar, which is a good deal decomposed, so that it is difficult to identify the species. It is, however, one of the plagioclastic group. There is a small quantity of a mineral, mentioned in my former paper *, which resembles an altered enstatite. Granules of iron peroxide, some epidote, a little apatite (?), and quartz, probably secondary, with calcite, and other alteration-products are present.

* Quart. Journ. Geol. Soc. vol. xxxix. p. 259.

No. II. Slightly more compact than the last described, with a sharper and smoother fracture. Under the microscope, the hornblende is seen to be slightly less abundant, rather more regular in external form and less frequently interrupted by enclosures. These, as well as some patches in the body of the slide, are occupied by a pale green viridite and irregular granules of a colourless mineral which may be dolomite. Felspar like that in the former slide, but rather more abundant, and accessory minerals occur as before.

No. III. (Half a yard from last specimen.) A mottled dark green and pale pinkish grey rock, looking slightly coarser than the last. Under the microscope the difference is not very material, except that there is more felspar, this now being the dominant mineral. The felspar is a little better preserved, and appears to be mainly plagioclastic. The extinction-angles are rather small, as if it were one of the varieties rich in silica. There is also a fair amount of quartz scattered about the slide. The rock, in short, is an ordinary diorite of fairly characteristic ophitic structure.

No. IV. Hornblende crystals, about ·3 in. in diameter, abundant; very rough fracture. Except for the greater size of many of the hornblende crystals and the decided predominance of that mineral, the description of No. I. will apply. The bastite-like mineral occurs associated with a granular, colourless mineral, probably of secondary origin, which I cannot name.

No. V. A still coarser rock than the last; hornblende crystals sometimes fully ·5 inch across and more conspicuously interrupted. Making allowance for this, the microscopic structure is not materially different from that of the last-named specimen. The sudden transition in the same crystal from the very dark brown to the almost colourless and rather fibrous hornblende happens to be particularly well exhibited (Plate XVI. fig. 2). There is also rather more calcite in this slide than in the others.

The isolated outcrop, mentioned above as probably connected with the main mass of picrite, is a greyish rock containing, in a rather compact base, small scattered whitish crystals. Under the microscope, it is seen to be holocrystalline, consisting mainly of very decomposed felspar, from which all distinctive characters have disappeared, and a much altered hornblende, now to a large extent replaced by an earthy-looking material almost opaque to transmitted light, and appearing of a pale grey colour with reflected light, something like leucoxene. There are some scattered granules of quartz, grains of iron peroxide, possibly ilmenite, some calcite, and a good many belonites of a nearly colourless mineral, which is frequent in diabases, and I think is sometimes described as apatite.

A specimen of the altered Skiddaw Slate, taken from about one foot distant from a junction with rock like No. I., is a hard compact brownish grey rock. Under the microscope it is seen to consist of very minute and ill-defined granules of quartz, associated with an abundant, colourless, fibrous, micaceous mineral, and with earthy granules. There is a fair amount of a brownish fibrous mica; ferrite, micaceous minerals, &c., are sometimes aggregated in clustered patches, as

may often be seen in various "spotted schists." Specks of a kaolinized mineral are also present.

About 500 yards to the south, another but smaller dyke-like mass of dioritic rock cuts the ridge of Long Side; beyond it is one yet smaller, and oval in shape, and then come three narrow dykes. I visited the second of these; it is an ordinary "greenstone"—probably a hornblendic diabase—rather decomposed. As I did not observe any boulders of the more characteristic picrite scattered above the line of the Little-Knott exposure, I deemed it needless to hunt out the remaining outcrops.

One point in regard to the boulders from Little Knott is, I think, worthy of notice as bearing on questions other than petrographical. The burn in the ravine below flows over a boulder deposit. This appears to be of some thickness and extends down the glen for a considerable distance like a scattered or "trailing" terminal moraine. I followed it for about 300 yards. It seemed to be composed almost wholly of picrite boulders, 3, 4, or even 5 feet in longest diameter. If then the whole mass corresponds in composition with the part which I saw, the united boulders would form a large mass of picrite rock. Besides this a rather high wall, enclosing a large field on the spur opposite to Little Knott, is almost wholly made up of fragments of the same rock. I think it no exaggeration to say that if all these erratics were replaced on the area mapped as occupied by picrite, they would form a conspicuous ridge. In considering the possibility of Little Knott being the source of the Anglesey boulders, the smallness of the exposure had always seemed to me a great difficulty, as they are comparatively common in that island. This difficulty, however, appears of much less account when we view the scattered boulders in the immediate vicinity*.

This mode of occurrence of the boulders suggests another consideration. The mass of boulders in the lower part of the glen has every appearance of a morainic deposit; but the highest point at which picrite is exposed cannot, I think, be more than 250 feet above the bed of the stream †, and a considerable part of the ridge must have been uncovered in order to allow of so great an accumulation of fragments. Hence the glacier can never have been very thick, say not more than 100 feet as a maximum, when it distributed the boulders. As they commence in force immediately below the line of outcrop, it must during the latter part of the time have been very much thinner. It was therefore a local glacier originating under the upper cliffs of Skiddaw and occupying the above-mentioned glen. It follows then that if boulders have been transported from Little Knott, at any rate to the Flintshire coast ‡, so as to occur in the drift, the only possible explanation is, that the glacier terminated in the sea and the boulders were conveyed by floating ice.

* I believe there is the same apparent disproportion between the outcrop of minette on Sale Fell and the boulders distributed thereupon.

† Little Knott itself is between the contour lines of 1000 feet and 1250 feet, probably about 1150 feet; the dyke in the bed of the glen is on the 900 feet line.

‡ As stated by Mr. De Rance, Quart. Journ. Geol. Soc. vol. xxxix. p. 260.

Further, the glacier above described belongs either to the earlier period of greatest glaciation or to the later or "valley glacier" period. If to the former, then all theories of vast ice-sheets melt away; if to the latter, we must suppose either that the interval between the two periods was long enough to allow of the accumulation of the needful store of picrite boulders on the flanks of the glen for transportation by the growing glacier of the later period, or that the erosive power of glacier ice is so slight that the shattered ridges of picrite were not materially diminished even in the period of ice-sheets, and that these preserved, without plundering, the stores accumulated in preceding geological periods.

I deem it needless to prove that these boulders have been transported on and not below the glacier, because the latter mode of transport, at best a rather hypothetical one, appeared to me irreconcilable with the evidence to be obtained on the ground. Hence I regard the district of Little Knott as bearing testimony adverse to the extreme theories of "ice, its extent and work," of which during the last twenty years we have heard so much.

Hornblende-Picrites of Anglesey and Caernarvonshire.

In the matter of the Anglesey picrites, I have obtained some further information. In 1883 during an afternoon's walk in the district between Ty Croes and the sea, I observed whole or broken boulders, not less than five in number, of which some details are given in the report of the Erratic Blocks Committee of the British Association *; but I felt some doubt as to the correctness of my identification of the rock in the supports of the Cromlech Barclodiad-y-gawras. (It will be remembered that here only the weathered surfaces of the stones can be examined.) But I have received from Prof. Hughes a supply of specimens from two masses of very similar rock which he has discovered *in situ* in Anglesey. As my engagements during the last eighteen months have made it impossible for me to visit that island, I am indebted to his kindness for the following information. The one rock occurs at Caemawr near Llanerchymedd, the other at Pengorphwysfa, $1\frac{1}{2}$ mile E.S.E, of Amlwch, both localities lying much in the same line, rather to the N. of N.E. of the district over which the boulders are scattered.

Prof. Hughes thus writes:—"With regard to the mode of occurrence of the Caemawr dykes, from which, I think, most of the boulders of Central Anglesey are derived, there is not much to say. They are a group of dykes of various composition and texture, occurring in the Arenig series a little below the zone of *Didymograptus Murchisoni*. Their trend, as seen on the surface, is approximately with the strike of the rocks, but I have not ascertained whether or not they generally coincide with the bedding for any distance. There are differences of texture between neighbouring dykes, and still greater differences, sometimes, between adjoining parts of the same dyke. The very light-coloured more coarsely crystalline specimen (see

* Volume for 1883 (Southport), p. 146.

below *b*) is from a portion of one of the most southerly dykes, which, in the rest of the mass, is of the usual dark green blotched colour (*a*). There is no sharp line between the two, but the light rock shades rapidly into the other as if it represented a difference in the material 'boiled up,' a defect in the mixing, a local accident affecting the cooling and crystallization or subsequent superinduced alteration, but not a later-intruded dyke. The Pengorphwysfa boss is a similar but larger mass, and shows the same but less marked and rapid variations. The boulders from Caemawr are found trailed to the south for miles. I was not looking out for them, but my impression is that they came to hand right up to Pen-y-Carnisiog and beyond."—T.M'K.H.

The specimens from the Pengorphwysfa boss vary from an ordinary compact "greenstone" to a moderately coarse rock consisting of hornblende crystals from ·2 to ·3 inch wide, and a greenish grey mineral. Under the microscope, hornblende is seen to be very abundant. There are, as above, brown crystals passing into green and containing serpentinous enclosures, with numerous smaller crystals and fibrous flakes thickly scattered over the slide and giving brilliant colours with polarized light: interspersed with the smaller of these is some felspar in small grains of irregular form and indefinite character, not indicating an ophitic structure, and decidedly less abundant than in the Little-Knott rock. Certain of the serpentinous grains with reticulate minute belonites suggest the former presence of enstatite rather than of olivine *. There are some grains of iron peroxide (? hæmatite), and perhaps a little apatite.

A second slide, cut from a slightly more mottled specimen, contains a rather larger quantity of a decomposed plagioclastic felspar.

One variety (*a*) of the rock from the southern dyke at Caemawr is macroscopically much like the last described, but on microscopic examination it presents this difference, that very little felspar can be detected; there is a fair amount of a pale yellowish serpentinous mineral, or rather of aggregated groups of small serpentinous minerals, which have most probably replaced olivine, or, perhaps in one or two cases, enstatite. Another peculiarity is that there are a fair number of crystalline grains of a mineral with its external angles not very well defined, often occurring in small groups. It is clear and almost colourless, though its cleavage and other cracks are often much stained, apparently by the formation of a brown decomposition-product (Plate XVI. fig. 1). It is one of the pale-coloured augites †.

Another specimen (*b*) from this dyke exhibits a variation as marked as any described in the Little-Knott rock, being a mottled dull green and whitish rock, a fairly typical specimen of the hornblendic gabbros frequent in North Wales. Under the microscope, felspar is seen to predominate, the crystals varying in size, so that the structure might be called porphyritic. Most of it is plagioclase,

* This is well seen in a slide lent to me by Prof. Hughes.

† A slide lent to me by Prof. Hughes confirms the above description.

probably labradorite. The pyroxenic constituent is much altered and is replaced by secondary microlithic products mostly of a hornblendic character. Besides the usual decomposed granules of iron peroxide, there is a fair amount of well-marked apatite, which is wanting in the other slides. No one would imagine that these specimens could have come from one and the same dyke.

I have to thank Prof. Hughes also for allowing me to re-examine specimens collected by the late Prof. Sedgwick and Mr. Tawney, now in the Woodwardian Museum, one of which is noticed briefly in my first paper *. It is now evident to me that in all probability the true picrite collected by Prof. Sedgwick from Penarfynydd (Aberdaron) forms a part of the olivine-diabase described by Mr. Tawney. In all the specimens there is the same characteristic of fair-sized hornblende crystals interrupted by serpentinous enclosures, so that we may regard this as another outcrop of a similar picrite. This also appears to exhibit the usual variability in mineral composition. Another series of specimens come from the neighbourhood of Clynnog, the the most characteristic being from a boulder under Gyrn Goch; but a similar rock occurs *in situ* at Pen-y-rhiwan (Coll. Tawney) †. These rocks are very similar to the picrites which I have been describing. I doubt whether there has been so much felspar as the authors of the earlier description supposed.

The variability of the mineral composition of the rocks described above is singular, but perhaps does not indicate quite so great a diversity of chemical composition as at first sight would appear. Looking at the table of analyses given in my last paper, we see that not seldom 1 per cent. of soda is present ‡. If this were employed in the composition of a felspar like labradorite $SiO_2=52{\cdot}9$, $Al_2O_3=30{\cdot}3$, $CaO=12{\cdot}3$, $Na_2O=4{\cdot}5$, the following constituents would be required to make up the felspar :—

$$\begin{aligned} SiO_2 &= 11{\cdot}7 \\ Al_2O_3 &= 6{\cdot}7 \\ CaO &= 2{\cdot}7 \\ Na_2O &= 1{\cdot}0 \\ \hline & \ 22{\cdot}1 \end{aligned}$$

or more than one fifth of the whole would be felspar. Besides soda there is often a little potash. Now as the amount of felspar in all of these picrites which I have examined is nothing like one fifth of the whole mass, it follows that not only the potash must enter into the composition of other minerals (*e. g.* a mica, often present) but also that some of the soda must be so employed. Further if all the soda in the specimen analyzed by Mr. Phillips went to form felspar, only about 6 parts of alumina would be required; yet the rock contains

* Quart. Journ. Geol. Soc. vol. xxxvii. p. 139: for full description see Geol. Mag. Dec. 2, vol. vii. p. 208.

† For description see Geol. Mag. Dec. 2, vol. vii. p. 457.

‡ In the Anglesey specimen analyzed by Mr. J. A. Phillips there is (mean), $Na_2O={\cdot}915$, $K_2O={\cdot}125$. Total of alkalies $=1{\cdot}04$.

about 10·9. Thus there is 4·5 at least to spare, more than is wanted for a mica. Hence in the one case we may have, for instance, a rock composed of more than one variety of hornblende (pargasite, arfvedsonite &c.), a potash-iron mica, olivine or enstatite, and a little felspar; in the other case, if non-aluminous and non-alkaline hornblende were formed, we might have more than half of the rock composed of felspar *. Thus although there is probably some variation of chemical composition, the great difference in the component minerals may be quite as much due in some cases to a difference of circumstances.

I have carefully revised all my collection of slides in the hope of discovering characteristics which might help in the identification of the boulders, but, as might be expected in the case of rocks which exhibit so much variability (due no doubt in part to their coarseness), I have not met with much success.

I do not find any distinct traces of enstatite in slides cut from boulders from Pen-y-Carnisiog, Peny-y-cnwc, the gate-post, or the road-side near Ty Croes, but in each, a colourless augite is more or less distinct. This mineral is not present in the boulder on the shore at Porthnobla, but it contains a mineral like enstatite. The Pengorphwysfa rock exhibits the augite and some enstatite; that from Caemawr, augite and perhaps enstatite. In the Little-Knott slides I find enstatite, but have not certainly identified augite; here, however, it is generally not difficult to detect some felspar. This accords with the result of the partial analyses quoted in my last paper, so that it is a less typical picrite than the rock of the Welsh boulders. Thus the lithological evidence rather favours the derivation of the Anglesey boulders from dykes in that island, and this appears from the evidence supplied by Prof. Hughes to be most probably correct.

The specimens sent to me from Caemawr and Pengorphwysfa are, indeed, not so coarsely crystalline as some of the boulders. This predominance of coarse varieties in the boulders (true also of the Little-Knott rock) may be an instance of a survival of the fittest; for I noticed at Schriesheim (and I have seen it elsewhere in doleritic rocks) that the most coarsely crystalline parts had a nodular habit, and were often well preserved, when the more fine-grained parts immediately around them were decomposed †.

Hornblende-Picrite Boulder near St. Davids.

Not long after the reading of my last paper Dr. H. Hicks informed me that he had recently discovered a boulder of hornblende-picrite in

* If the alkaline percentage were 2·5 (and the joint amount is often quite that), then, assuming a felspar of the composition of labradorite, 55·5 of the rock would be felspar.

† But the Henslow collection contains specimens, labelled "N. of Llanerchymedd," as coarse as any boulder which I have found. Whether these come from rock *in situ* or not, they bring this variety very close to Caemawr. Mr. Harker also has sent me specimens of boulders from near Llanerchymedd quite typical of those which occur in the district south-west of Ty Croes.

the neighbourhood of St. Davids, and to him I am indebted for specimens and for the following note as to the locality. He says :—"The boulder is somewhat rounded ; its longer axis, which lies nearly S.E. and N.W., measures about a yard. A transverse section is slightly triangular, the shorter sides measuring respectively about 16 in. and 22 in. It lies on the promontory forming the east side of Porthlisky harbour *, resting immediately on Dimetian rock, surrounded by an uncultivated area overgrown by gorse and heather. The striæ along this coast usually point from N.W. to S.E.; but it is clear that very many of the boulders scattered over it must have come from the high land in the N.E. of Pembrokeshire, the Precelly range. There is ample evidence of local till, and in places (at considerable elevations) of marine sand with transported boulders, fragments of flint being common among them. I fancy this points to the derivation of some of the materials, including possibly certain boulders, from a N.W. source."

The surface of the boulder (which is overgrown with lichens) is rough and lumpy. A brown staining extends inward for less than ·1 in. The rest of the rock is in good preservation and is wonderfully like that of the Pen-y-Carnisiog boulder, looking perhaps even fresher and thus closer to the Schriesheim rock. The larger crystals of hornblende are sometimes quite $\frac{3}{4}$ inch in diameter. As in the other cases the general colour is a dull somewhat mottled green, with a few whitish specks †. The hornblende crystals on a smooth-cut surface have a slightly metallic and silvery lustre. My previous papers render a minute description of the microscopic structure unnecessary, so, referring generally to them and especially to the account of the Pen-y-Carnisiog specimen, I will only call attention to one or two points of difference. There are a few grains of olivine fairly well preserved (Plate XVI. fig. 4). The larger hornblende crystals, in addition to the serpentinous enclosures, which in all probability have replaced olivine, contain a fair number of crystalline grains of a colourless augite. This mineral also occurs in considerable quantities in the slide, frequently with a tendency to grouping. There the crystals are sometimes set in a serpentinous ground-mass, and sometimes associated with a pale-coloured hornblende, and occasionally with grains of another variety of a serpentinous mineral which appears to be subsequent in consolidation. This augite has been already noticed in my former papers ; but in the cases there described it was often not very definite in form or cleavage, and had a dusty look as if partially decomposed. Instances of the latter variety occur in these slides also ; but the majority of the crystals are beautifully clear, and are well defined, showing characteristic transverse and longitudinal sections and cleavage, and giving such clear brilliant colours with crossing nicols that at the first glance one might take them to be olivine. They appear to have a slightly granular, fibrous or silky structure (Plate XVI. fig. 6). They must,

* Immediately south-west of the letter S in the Survey map.

† These appear to me to be too soft for felspar ; probably they are a steatitic mineral, like that which mottles certain serpentines.

I think, be anterior in consolidation to the brown hornblende, as their crystals do not indicate definite orientation or any relation with it. The brown hornblende exhibits the usual transition to a pale green or even colourless variety with a slight alteration in the extinction-angle. The serpentinous mineral in which some of these white augite crystals are imbedded is very faintly tinged with yellowish green and has but a slight influence on polarized light, resembling a steatitic mineral. In other parts of the slide the colour is a little stronger, and the mineral gives brighter tints between crossed nicols, showing the aggregate fibrous structure often seen in serpentines. The serpentinous grains mentioned above as also interspersed in this ground-mass, are rather irregular in form, though showing some tendency to rectilinear boundaries; many of them exhibit one well-marked cleavage. They are rather a stronger yellowish olive-green in colour, frequently crowded with dusty-looking granules containing occasional specks of opacite and numerous minute belonites *. With polarized light they exhibit a minutely fibrous, aggregate structure with fairly bright colours (Plate XVI. figs. 3, 4). I believe the mineral to be an altered enstatite. I have also noted one or two flakes of brown mica, more or less altered.

In conclusion I will venture a few remarks on the paragenesis of the minerals in this interesting group of rocks, including therewith the Schriesheim rock and a picrite from Gippsland (Australia). The latter has been described by me in the 'Mineralogical Magazine,' vol. vi. p. 54, and is microscopically closely allied to them except that the hornblende is green instead of brown; in this also unaltered olivine still remains. I fear, however, that they will state difficulties rather than solve them. We find olivine (or serpentinous pseudomorphs of it) included in brown and green hornblende and in brown mica, also in light-brown augite (if we include the Inchcolm picrite and that from Hain). Olivine also is included in enstatite in certain serpentines. In other serpentines we have enstatite separately crystallized; and in some of the above picrites serpentinous products which suggest the former presence of enstatite rather than of olivine occur in a similar manner.

Now as regards the augite, there is, it appears to me, some reason to believe that we can have the following succession of alterations in the above group of rocks—light-brown augite, sometimes practically clear in thin sections; clove-brown hornblende †; green hornblende; colourless, rather fibrous hornblende. In these changes the augite undergoes what I may call for distinction the "uralitic change," because there is apparently no alteration in the outward form of the crystal. Another line of change appears to be the formation of distinct crystals of green hornblende or of abundant microliths of actinolite. This we may term "actinolitic change." In some rocks

* Like those described by me in the Porthnobla specimen, Quart. Journ. Geol. Soc. vol. xxxix. p. 255.

† If not there are very singular cases of intergrowth of the pale augite and the brown hornblende.

the augite appears to assume the form of diallage * before either uralitic or actinolitic change. What then is the history of the perfectly clear, rather silky, well-defined augite crystals described above as included in brown and green hornblende and perhaps also in enstatite? Are they parts of the original light augite left unchanged? or are they secondary products? or are they original enclosures? Their definite crystalline form, whether within or without the hornblende, their sharp demarcation from the strong-coloured hornblende, are unfavourable to the first or second supposition and favourable to the third (Plate XVI. figs. 4, 5, 6). But still their perfect preservation in rocks where the other constituents appear more or less altered is strange. Also what variety of augite are they? Their general appearance suggests an augite allied to diopside, which, indeed, appears to be a rather stable mineral. At present I must content myself with stating the facts and the inferences to which they appear to lead, and must leave it to further work or other workers to resolve the difficulty.

It results, however, that a group of rocks, characterized by the predominance of magnesian bisilicates and unisilicates, by the frequent enclosure of olivine, perhaps also of a magnesian bisilicate, in the larger augite or hornblende crystals, and by the infrequency of felspar, of which we may take the Schriesheim, Gippsland, and Inchcolm picrites as characteristic types, besides that of Hain—rocks which, on the whole, exhibit a tendency to graduate into normal olivine-diabase rather than into true peridotites, though occasionally they come very near to the latter—occur not only in boulders, but also *in situ* at Little Knott, and at two localities both in Anglesey and in the Lleyn peninsula. Even if no others be found, which is very likely, at any rate in South-west Wales (the more probable home of the St. Davids boulder), this is a fair list of localities for a rock the occurrence of which in England and Wales was only chronicled in 1881.

EXPLANATION OF PLATE XVI.

Fig. 1. Group of crystalline grains, external form not generally perfect, of a pale-coloured augite, associated with a dark staining. (S. Dyke, Caemawr, page 516.)

2. Part of a slide of the Little-Knott rock, illustrating the rapid change (with crystalline continuity) from a dark brown hornblende to an almost colourless greenish slightly fibrous variety. (Slide No. V., page 513.)

3. Grain of a serpentinous mineral (*a*) showing one well-marked cleavage, and probably an altered enstatite, with brown hornblende (*b*), augites &c. in a serpentinous ground-mass (*c*). (Boulder, Porthlisky, page 519.)

4. Grains of somewhat blackened olivine (*a*) associated with grains of a yellowish serpentinous mineral (*b*) and colourless augite (*c*) in a ground-mass of similar minerals, hornblende, a little decomposed felspar, &c. (Boulder, Porthlisky, page 519.)

5. Grains of two varieties of augite (*a*, *b*) enclosed in a crystal of brown hornblende. (Boulder, Porthlisky, page 519.)

6. Crystals of colourless augite in a pale greenish serpentinous ground-mass. (Boulder, Porthlisky, page 519.)

* I have seen this also exhibit "schillerization."

Discussion.

Dr. Evans remarked on the interest attaching to the determination of the locality and of the distribution of the specimens.

Dr. A. Geikie pointed out the remarkable changes in texture and composition in the rocks of this class within short distances. This is illustrated by the Inchcolm and Bathgate rocks and by certain intrusive rocks in the north of Ireland.

Mr. Teall pointed out that the term picrite, first used by Tschermak, had been applied by later writers to rocks differing somewhat from the original type; and also that Cohen, who applied the term to the Schriesheim rock, under the mistaken idea that the dominant bisilicate was diallage, now wished to withdraw this name from the rock altogether.

Prof. Seeley stated that the specimens of the Henslow collection are all recorded, with full particulars concerning them, in catalogues which are preserved in the Woodwardian Museum.

Mr. Rutley thought that possibly picrite was an altered condition of basalt. He regarded the statements made by the late Mr. Clifton Ward as very justifiable.

Mr. Hudleston was glad to learn that the rock which yielded the boulders of hornblende-picrite, first noticed by the President, had at length been discovered in Anglesey, so that North Wales was independent of the Lake District for its supply. He asked for further information concerning the mode of its occurrence *in situ*.

Prof. Judd defended the use of the term picrite, and thought that the Author, in giving the name of hornblende-picrite to the rock he had been the first to define, was exercising a wise discretion.

Mr. Bauerman thought that picrite, or names very similar to it, had been formerly applied to minerals. He did not think it wise to give similar names to minerals and rocks.

Mr. Harker said that the two localities where the rock occurred in Anglesey are both large dykes intrusive in Arenig rocks. In the Lleyn peninsula are large intrusive bosses. In all cases the rocks vary in texture and composition within very short distances. The Henslow catalogue does not state whether the rocks were collected *in situ* or from boulders.

Dr. Hicks thought the boulder at St. Davids must have been transported from a distance, though it is possible that the rock would be found *in situ* in North-east Pembrokeshire.

Prof. Bonney said the name "picrite" was a well-recognized name for a rock, and he had employed it as such. It was absurd to suggest that such a rock might be derived by decomposition from basalt, as it differed much both chemically and mineralogically. The rock was not, in any proper sense of the term, a decomposition-product at all, but rather a recomposition of another rock. Nothing he had said in his paper could possibly be represented as reflecting on the late Mr. Clifton Ward, who had recognized the abnormal nature of the rock, and had done such excellent work in his day.

38. Supplementary Notes *on the* Deep Boring *at* Richmond, Surrey.

By Prof. John W. Judd, F.R.S., Sec. G.S., and Collett Homersham, Esq., F.G.S. (Read June 24, 1885.)

At the time when our former communication to the Society was published (November 1884*), we were able to report that this very interesting well had, on the 15th of October, reached a depth of 1409 feet. We now propose to chronicle the subsequent progress and termination of the undertaking, adding some new observations which have an important bearing upon the subjects discussed in that paper.

Subsequently to the date mentioned, many very serious difficulties were unfortunately encountered in carrying on the work; but, in spite of these disappointments, the Richmond Vestry, acting under the advice of their engineer, Mr. S. C. Homersham, determined to persevere in their efforts so long as they felt justified in incurring the necessarily large outlay. After many vexatious accidents and consequent delays the work had, by the end of the year 1884, reached the depth of 1442 feet. At this point the Richmond Vestry, to whose spirit of enterprise geologists are so greatly indebted for the important evidence afforded by this undertaking, decided that they could no longer incur the responsibility of further expenditure, and gave orders to stop the work.

The work did not come to an end immediately, however; for the contractors, Messrs. T. Docwra and Son, with great public spirit, offered to attempt to make further progress with the important undertaking at their own expense and risk. All their efforts, however, succeeded only in deepening the well to the extent of 5 feet, and the boring was finally abandoned when it had reached the depth of 1447 feet. The well at the bottom has a diameter of nearly 8 inches, and the lowest cores brought up have a diameter of $4\frac{3}{4}$ inches. The well is lined to within 80 feet of the bottom.

Unfortunately, no increased supply of water was obtained by the deepening of the well from 1409 to 1447 feet.

It will thus be seen that the Richmond well is actually deeper than any other well in the London basin by 145 feet; but if we reckon from the absolute level of the Ordnance datum line, it will be found to have reached a point 312 feet lower than that attained by any previous undertaking of the kind.

Although it was found impracticable to plug the bore-hole at the extreme depth reached, for the purpose of temperature-observations, a thermometer supplied by the British-Association Committee on Underground Temperatures was let down to the bottom and kept there for six days. Boring operations had ceased eleven days previously, and the temperature registered in this observation was $76\frac{3}{4}°$ F. The temperature of the air during the time the thermo-

* Quart. Journ. Geol. Soc. vol. xl. (1884) p. 724.

meter was kept down varied from 45° to 57° F., and that of the water overflowing at the surface was 59° F.

Comparing the result thus obtained with that arrived at by the observations previously recorded at the depth of 1337 feet, we find that the increase in temperature for the last 110 feet is only $1\frac{1}{4}$° F., or at the rate of 1° F. for 88 feet. With an assumed surface-temperature of 50° F., the average increase for the whole depth of the well would amount to 1° F. for 54·09 feet of descent, the result previously obtained being 1° F. for 52·43 feet of descent.

The additional 38 feet of strata sunk through all evidently belong to the same series of beds, variegated sandstones and marls, which had been penetrated previously to the depth of 170 feet. The details of the strata passed through in the last 38 feet were as follows:—The beds (18)* "soft red and white sandstones, finely laminated in places," had a total depth of about 32 feet; then succeeded—

	ft.	in.
19. Mottled sandstones, becoming intensely hard at their base	4	0
20. Softer mottled sandstone with "clay-galls"	6	0
21. Finely-laminated soft mottled sandstones	12	0
22. Very hard red sandstones, the joint-planes coated with green incrustations	1	3
23. Soft green shaly rock......................	0	9
24. Hard red sandstone, like 22......................	1	3
25. Dark-red sandstone, softer	1	9
26. Very fine-grained red sandstone	1	0
27. Very hard red sandstone, which had to be ground away, and could not be brought to surface in cores......................	4	0
28. Hard white fine-grained sandstone, with no lamination, but exhibiting a rude dip	4	0
Total thickness of variegated strata underlying the Great Oolite ...	208	0

The following apparent dips were measured in the cores brought up in the last 38 feet:—

	Dip.
At 1411 feet from the surface	27°
,, 1412 ,, ,, ...	28°
,, 1420 ,, ,, ...	26°
,, 1421 ,, ,, ...	28°
,, 1431 ,, ,, ...	27°
,, 1433 ,, ,, ...	26°
,, 1437 ,, ,, ...	32°
,, 1438 ,, ,, ...	32o
,, 1443 ,, ,, ...	33°

With regard to the question of the geological age of these strata we have, unfortunately, but little fresh evidence to offer.

The new facts derived from the examination of the dips exhibited by the cores are almost conclusively in favour of these rocks having a true dip of about 30°, complicated by much false-bedding. This is indicated by the circumstance that the finely-laminated strata exhibit the most variable apparent dips, while those beds with very imperfect stratification, which probably show true dip, nearly always

* *Loc. cit.* p. 750.

give angles of about 30°. This is the case with the lowest cores brought up in this boring.

By some this high dip, and the necessary inference of unconformable relation between these variegated strata and the overlying Jurassic and Cretaceous rocks, may be regarded as telling in favour of their pre-Carboniferous age. But it is by no means impossible that Poikilitic strata in this area were disturbed and denuded before the period of the deposition of the Great Oolite. The lowest beds exposed in the boring are certainly much more like those of the New Red than of the Old Red. It must be remembered, too, that in Northamptonshire somewhat similar variegated strata have actually been found intercalated with the Carboniferous series. It cannot fail, however, to be a constant subject of regret to geologists that no more precise evidence concerning the age of these strata was obtained.

With respect to some other strata passed through in this well, interesting additional evidence has been obtained since the reading of the paper.

At the depth of 704 feet in this well we indicated the existence of a curious conglomerated chalk, covered by 15 feet of hard chalk. The former was referred to the Zone of *Belemnites plenus* in its *remanié* condition; and the latter, it was suggested, might not improbably be referred to the "Melbourn Rock" of Mr. A. J. Jukes-Browne. Since the reading of the paper, we have been indebted to Mr. William Hill, Jun., F.G.S., of Hitchin, for a number of facts and specimens which prove conclusively the identity of the Melbourn Rock with that which occurs at this horizon under Richmond.

Mr. Hill, who had long studied the microscopic characters of the different beds of the Chalk series, and had traced the different zones through a large part of the Midland area, on reading our account of the conglomerated chalk of Richmond, at once sought for it along the line of outcrop of the Melbourn Rock. The specimens he has kindly submitted to us prove that a precisely similar bed everywhere forms the base of the Melbourn Rock of the Midlands, and that there is the strongest resemblance in microscopic characters between that rock and its conglomerated base in the district he has studied and in the London basin. The recognition of this important horizon cannot fail to greatly facilitate the separation of different zones in the Chalk in this country.

With the aid of Dr. Hinde, F.G.S., and Prof. T. Rupert Jones, F.R.S., we have further investigated the interesting specimens of chalk-marl obtained from the Richmond well. On dissolving the chalk-marl in dilute acid, a residue, amounting in some cases to no less than 50 per cent of the whole, is left behind. By washing this residue many beautiful specimens of fossils have been obtained. Portions of the spicular mesh of hexactinellid sponges are common, and in some cases Dr. Hinde has been able to determine the genera and species. Very abundant, indeed, in some cases are silicified prisms of the shell of *Inoceramus*; these sometimes, indeed, make up a large part of the mass of insoluble residue of the chalk-marl.

With them occur a number of partially silicified Foraminifera. The forms usually obtained by the treatment of the chalk-marl with acid are arenaceous types like *Bulimina* (*Ataxophragmium*), *Textularia* (*Plecanium*), and *Verneuilina*. In these a more or less perfect cohesion of the sand grains composing the shells has been brought about by the deposition of siliceous material between them.

But it is with respect to the Jurassic deposits, the existence of which under the London basin was previously unknown, that the evidence afforded by the Richmond boring is of such great value and interest.

Since the reading of our paper, in which we endeavoured to define the position and relations of the Upper, Middle, and Lower Oolites respectively in the South-east of England, a new and most valuable piece of evidence has been obtained, which confirms in a very striking manner the conclusions at which we then arrived.

During the progress of the Dockyard Extension works at Chatham, H.M. Government have had occasion to sink two deep wells, one of which has penetrated the whole of the Cretaceous strata and reached the underlying rocks. The results have been communicated to Messrs. Whitaker and Topley for the use of the Geological Survey, and we have the courteous permission of the Director-General to publish the interesting details with which the officers of the Survey have furnished us.

The deepest well at Chatham attained a depth of 965 feet, and the strata passed through were as follows*:—

Surface 16 feet above Ordnance datum.

	Thickness. ft.	Depth from surface. ft.
Alluvium, gravel, and Thanet-sand	27	
Chalk	682	709
Gault	193	902
Lower Greensand (sandy beds)	41	943
Dark-blue clay (Oxfordian)	22	965

The first point which strikes us in this very interesting section is the remarkable way in which the Lower Greensand has thinned out in a distance of 7 miles from Maidstone (at which place it has a thickness of 225 feet, and includes the thick calcareous masses of the Kentish Rag) to a comparatively insignificant and purely sandy representative.

The blue clays underlying the Lower Greensand were not unnaturally taken for Wealden in the first instance, but a number of fossils washed from these clays by Mr. Creswick, of the Admiralty Office of Works, were found to be suspiciously like Oxford-clay forms, and on being submitted to Messrs. G. Sharman and E. T. Newton, F.G.S., of the Geological Survey, they were identified as follows:—

* A short notice of the strata passed through in this well has already been given by Mr. Whitaker in his 'Guide to the Geology of London and the Neighbourhood' (4th edition, 1884), pp. 19, 21. A more detailed account of them will be given in a forthcoming publication of the Geological Survey.

Ammonites crenatus, *Brug.*
—— hecticus, *Rein.*
—— Lamberti, *Sby.*
—— plicatus?, *Sby.*
—— (minute forms, possibly young).
Belemnites, sp.
Alaria trifida.
Gasteropoda (very minute).
Astarte, sp.
Corbula?
Pecten, sp.
Pentacrinus Fisheri, *Baily* (*Forbes's MS.*)?
—— sigmaringensis?, *Quenst.*
Pentacrinus, sp.
Cidaris, sp. (plate and small spine).
Acrosalenia (?) (small spine).
Crustacean claws and limbs.
Bairdia (near to Juddiana, *Jones*).
Serpula vertebralis, *Sby.*
——, sp.
Coral (small turbinate).
Cristellaria rotulata, *Lam.* (var. with cupped centre and raised septa).
—— —— (var. with smooth exterior).
—— crepidula, *F. & M.*
Wood.

The evidence of these fossils is conclusive that the strata which contain them are not only of Oxfordian age, but that they belong to the middle portion of the Oxfordian, the Zone of *Ammonites bimammatus* of Oppel or the Zone of *Ammonites Lamberti* of English authors.

It thus appears that the Wealden deposits, which have such an enormous thickness (2000 ft.) in the Weald area proper, and are said to have been proved to the depth of 600 feet only 7 miles off at Maidstone, have thinned out completely within 7 miles of the Lower Greensand escarpment.

For the first time, then, we have direct evidence of the position of outcrop under the Cretaceous rocks of strata of Middle-Oolite age in the South-east of England. The existence of such strata was inferred from the position of the Upper Oolite as revealed in the Wealden boring at Battle, and from that of the Lower Oolites in the borings at Richmond and at Meux's Brewery, and was supported by the fact of the presence of numerous fossils derived from them in the Lower-Greensand strata cropping out from beneath the North Downs. From this evidence we were enabled to indicate with considerable precision the exact latitude in the south-east of England where the Middle Oolite might be expected to occur under the Chalk. The Chatham well has supplied the most conclusive evidence that our reasonings on the subject were well founded.

The important modifications of the views hitherto held by geologists concerning the depth at which rocks yielding coal and water respectively may be expected to be found in the south-east of England, which result from the discovery of the wide distribution of Jurassic rocks beneath the Cretaceous strata, have been already dwelt upon, and the justice of the conclusions arrived at has been proved by the important revelations of the Chatham well.

Discussion.

The President congratulated the authors on the important additions made by these borings to our knowledge of the geology of south-eastern England. He considered that the comparatively high

dip rendered it more probable than ever that the red beds were of Palæozoic age.

Prof. Prestwich said that the section was the most interesting yet recorded in the London district. The observation of the dip was new and important, as it coincided with the previous one noticed at Meux's Brewery, as well as those at Harwich and Kentish Town, and tended to show that the beds are probably not New but Old Red Sandstone like the Devonians of western England and the north of France. The temperature-observations agreed very nearly with those made at Kentish Town.

Mr. Bauerman remarked that the paper dealt with one of the most interesting subjects in the geology of southern England. He regretted that the Oxford Clay had again made its appearance in the Chatham boring, as showing a probable great thickness of the Oolites. The occurrence of Old Red at Richmond was also disappointing. He thought that a boring was wanted in the Kennet Valley between Reading and Devizes.

Mr. Topley said that the establishment of fixed horizons in the Chalk underlying London would aid greatly in mapping the subdivisions of that formation to the south. He regretted the absence of Mr. Whitaker, who, with Mr. Newton, had been engaged in working out the question. Mr. Creswick had washed out the fossils from the Chatham boring, and he had the credit of being the first to suggest their Oxford-Clay age. He had himself called attention to the Chatham boring when Prof. Judd's previous paper was read, but at that time, no fossils having been obtained, he supposed that the Oxfordian beds were Wealden. He suggested a comparison of the bottom-beds of the Richmond well with specimens from the Crossness boring now exhibited. He also called attention to a specimen from the bottom-beds of the Harwich boring, in which *Posidonomya* was said to have occurred.

Prof. T. Rupert Jones stated that the *Posidonomya* from the Harwich boring was examined by him, and undoubtedly belonged to that genus. He asked whether the Oxford Clay at Chatham contained Entomostraca as some Wiltshire specimens did.

Dr. C. Le Neve Foster inquired whether Prof. Judd was satisfied that the boring was vertical, as borings with the diamond-drill frequently deviated much from their initial direction at no considerable depth. This was of much importance in considering the question of dip as determined from the cores extracted.

Prof. Judd said that he would not enter into the vexed question of the age of the beds. All the evidence which could be obtained was given in the paper, but it was admitted that uncertainty still remained. In the case of the Richmond well the boring could not have deviated much from the vertical direction.

39. *Note on the* Zoological Position *of the Genus* Microchœrus, Wood, *and its* Apparent Identity *with* Hyopsodus, Leidy. By R. Lydekker, Esq., B.A., F.G.S., &c. (Read June 24, 1885.)

In 1846 the late Mr. S. V. Wood described * and figured the palate and left ramus of the mandible of a small mammal from the Upper Eocene of Hordwell, under the name of *Microchœrus erinaceus*, and considered that it was allied to *Hyracotherium*; although the specific name appears to indicate that he had a suspicion of other affinities. In 1870 Prof. J. Leidy † proposed the generic name of *Hyopsodus* for a small mammal from the reputed Upper Eocene of Wyoming, the remains of which were figured and described in a later work ‡, and were also regarded as indicating an animal allied to *Hyracotherium*. A recent comparison of the type specimens of *Microchœrus*, which are now in the British Museum (No. 25229), with Prof. Leidy's figures of *Hyopsodus* has convinced the writer that the two forms are extremely closely related and, in his own opinion, generically identical. The English form, of which the right upper dentition is figured on an enlarged scale in the accompanying woodcut, agrees in size with *Hyopsodus vicarius*, Cope §, and the resemblance is so close that it

Microchœrus erinaceus. *The Right Upper Dentition, from the palatal aspect.* ×2.

is difficult to point out even specific differences; the former shows, indeed, a minute accessory column in the valley external to the true main outer columns in the upper true molars, which is wanting in Prof. Leidy's figure of *H. paulus*, but whether present or absent in *H. vicarius* cannot be determined from Prof. Cope's figure. In any case the absence or presence of this column would not, in the present writer's opinion, be a character of more than specific value.

The figured American specimens of *Hyopsodus* do not show all the anterior teeth, and in this respect the type of *Microchœrus* is of

* 'Charlesworth's London Geological Journal,' No. i. p. 5, pl. ii. figs. 1 and 3 (1846).

† Proc. Ac. Nat. Sci. Philad. 1870, p. 110.

‡ 'Contributions to Extinct Vertebrate Fauna of the Western Territories' (Rep. U. S. Geol. Surv.), pp. 75–80, pl. vi. (1873).

§ *Vide* Amer. Nat. 1885, p. 460, fig. 3.

great importance. In the cranium there are altogether nine teeth on each side. The last three are true molars, in advance of which are two molariform premolars; the four teeth in front of the latter are caniniform, and at least the two first are inserted in the premaxilla. As the maxillo-premaxillary suture is not visible, it is impossible to be sure of the homology of the third and fourth teeth; but the writer is inclined to regard them respectively as the third incisor and the canine, although they may be the canine and the antepenultimate premolar. The upper dental formula will be therefore either I. 2, C. 1, Pm. 3, M. 3, or I. 3, C. 1, Pm. 2, M. 3. The innermost incisor is separated by a wide interval from the homologous tooth of the opposite side, in which respect it agrees with *Erinaceus* and several other Insectivora, and differs widely from all Ungulates. The small size of the canine (whichever this tooth be) and the caniniform incisors are marked insectivorous characters.

The lower jaw is reported to have been perfect when first discovered, but was broken during a journey to Paris. In its present condition it comprises the middle portion of the ramus, with the three true molars and the last premolar; but the two extremities have been restored in wax; the restoration of the anterior extremity is totally erroneous, there being a huge canine, which could not possibly have belonged to such an animal. In the figure there are shown three equal-sized premolariform teeth in front of the true molars, then a very minute tooth, and then a larger caniniform tooth with a considerable forward inclination; but it is uncertain whether this is correct. Another portion of a right ramus in the Museum from the same locality shows two premolariform teeth in front of the true molars, and two empty alveoli in advance of the former, which incline forward as in *Erinaceus*; but it is not easy to determine their serial homology.

The dentition of *Microchœrus* agrees so closely with that of *Erinaceus* that the writer has no hesitation in placing it in the same order. The cusps on the true molars are decidedly lower than, and differ considerably in arrangement from, those of *Erinaceus*, the difference being so great as, in his opinion, to forbid the inclusion of the two genera in the same family. The name *Hyopsodus*, if, as is almost certainly the case, that genus be identical with *Microchœrus*, should be superseded by the latter; and under any circumstances both the American and English forms must be placed in the same family. Prof. Cope*, in discussing the affinity of *Hyopsodus*, associates it with the lemurine *Adapis*, but remarks that many of the genera which he provisionally includes in the same group present such marked resemblance to the Insectivora that he is unable to say whether they should be referred to that order or to the Lemuroid Primates, there being strong evidence of a complete transition between the two.

The identity or, at least, the intimate affinity of *Microchœrus* and *Hyopsodus* is another instance of the close connection existing between the Upper Eocene and Lower Miocene Mammalian fauna of

* *Op. cit.* pp. 459, 460.

Europe and that of the reputed equivalent strata of North America, so remarkably exemplified by the occurrence in both of genera like *Hyænodon*, *Oxyæna*, *Proviverra* (*Stypolophus*), *Elotherium*, *Hyopotamus*, *Coryphodon*, *Pachynolophus* and *Hyracotherium* (*Orohippus*).

In conclusion it appears that *Microchœrus erinaceus* is by no means an uncommon form in the Eocene of Hordwell, since the British Museum possesses several fragments in addition to the type, and there are several imperfect specimens of the upper and lower jaws in the Woodwardian Museum at Cambridge.

40. *On the* Igneous *and* Associated Rocks *of the* Breidden Hills *in* East Montgomeryshire *and* West Shropshire. By W. W. Watts, Esq., M.A., F.G S. (Read June 24, 1885.)

I. Literature.

Murchison, Sir R. I. Silurian System, p. 290, *et seq*. 1839.
——. Siluria, p. 89. 1859.
Morton, G. H. On the Geology and Mineral Veins of the country around Shelve, Shropshire, with a notice of the Breidden Hills. Proc. Liverpool Geol. Soc. pp. 40, 41. 1868–69.
Symonds, Prof. W. S. Records of the Rocks, p. 89. 1872.
Ramsay, Sir A. Geological Survey of N. Wales, p. 328. 1881.
Randall. Severn Valley, pp. 120–122. 1882.
La Touche, Rev. J. D. Geology of Shropshire, p. 12. 1884.
Vine, G. R. Quart. Journ. Geol. Soc. xli. p. 109. 1885.
Geological Survey. Map. Sheet 60 N.E. 1850 and 1855.
——. Horizontal Section. Sheet 35. 1853.

II. Introduction.

The rocks described in this paper occur in a district on the borders of Shropshire and Montgomeryshire, on the east side of the Severn, about 12 miles W. of Shrewsbury and 6 miles N.E. of Welshpool. They are mapped by the Geological Survey, but no detailed description, except a few notices in Murchison's works, has yet been published.

There are three chief parallel ridges running N.E. and S.W. The two westerly ones, called the Breidden or Rodney's Pillar Hill (1143′)—extending northwards as far as Brimford Wood—and the Criggan, are composed of intrusive basic rock, and of this there are also one or two other little hills,—the Garreg near Trewern and Foel Coppice to the south, Belan Bank rising out of the alluvial plain of the Severn, and two small hills to the north. The easterly ridge, whose chief summits are Moel-y-Golfa (1199′), Middletown Hill, Bulthey Hill, and Bausley Hill, consists of lavas, ashes, and conglomerates of an intermediate type. Associated with these igneous rocks are shales, sandstones, and mudstones, which appear to be an inlier of the Bala rocks of Shelve reappearing under the Silurian synclinal of the Long Mountain to the S.E., which also seem to reappear as a tiny inlier at Buttington, and are apparently continued further to the S.W. in a strip of similar rocks to the E. and S.E. of Welshpool.

In this paper I propose to describe the contemporaneous and intrusive igneous rocks of the region, and to give a short account of the sedimentary rocks connected with them. And here I have great pleasure in expressing my most sincere thanks to Dr. Davidson and Prof. Lapworth for their kindness in determining my fragmentary fossils, and to Prof. Bonney and Mr. Allport for their ready help in

the difficulties which beset me in trying to make anything out of the petrology of rocks which have undergone so much decomposition as these.

III. Cambrian Rocks (*Sedgwick*).

These are best exposed in a little brook which rises between Bulthey and Bausley Hills, and, joining Belleisle Brook, cuts through the shales where they are not much traversed by eruptive rocks; but they are also seen in many isolated spots amongst the hills, particularly near Trewern. They consist of a series of slightly varying micaceous shales, dark grey and sometimes black in colour, easily fissile, slightly concretionary, and much broken by ironstained joints. Though appearing very likely to be fossiliferous, no fossils of any kind have been found in these Criggion shales, and their remarkable homogeneity renders it useless to attempt to establish divisions amongst them. The base of the shales is not seen, for the Severn alluvium covers it up. A remarkable band of sharply jointed, structureless, black quartzose grit occurs about 800 feet above the lowest beds seen; it is 20 feet thick, and is evidently much altered by a small dyke of diabase which penetrates the shales in its neighbourhood, and by its proximity to the intrusive mass of Brimford Wood, of which this dyke is an offshoot. There are two other dykes, one 60 feet and the other 30 feet wide, shown in the tributary. Along Belleisle Brook which follows the junction of the shales with coarse-grained diabase, the shales are much hardened, jointed, and altered. The dip of the rocks along the brooks varies from 80° S. to 60° S.E. and 60° S.S.E.; and, from the map, I should calculate that, below the conglomerates shortly to be described, there are about 2700 feet of rock where least disturbed, though the changes of dip and amount of intrusion render this estimate uncertain. Shales of precisely this character are observed to the S.W., often more or less altered and much disturbed in dip (particularly in the neighbourhood of the Criggan, Garreg, and other intrusive masses), and always unfossiliferous. I have not been able to identify the black grit to the south of this section.

The shales are followed by volcanic ashes, conglomerates, and even lavas which rise in the hills of the S.E. ridge. They are typically developed in the road-cutting between Bulthey and Bausley hills and on the northern crag of Bausley Hill where the rock is almost vertical. In a quarry near the road-cutting, spotted ashy beds and conglomerates are exposed, and these are followed by a massive conglomerate (of the road-cutting) dipping S.W. exclusively composed of volcanic rocks, and almost entirely of andesitic fragments, some of them reaching a diameter of 18 inches, set in a grey or spotted ashy matrix. The thickness of conglomerate shown in the road-cutting is 110 feet. In Bausley Hill* shales and ashy grits are intercalated amongst the conglomerates, and consequently the series is thicker; a few fossils are found in the grits. In a small farmyard at the north end of Bausley Hill, above the conglomerates,

* Sil. Syst., 292.

occur greenish grey, barren, homogeneous or micaceous shales breaking into cuboidal fragments, alternating with more sandy beds and indurated grey grits with Graptolites, which pass into thicker-bedded and more obviously ashy grits weathering brown and containing shells, Trilobites, and rare Graptolites. These beds are actually overthrust and dip to the N.W. at 38°; but I think this is simply inversion, for precisely similar beds are common above the conglomerates, particularly at the south part of Bausley Hill, near a farm-house, where some of the same fossils have been found. These localities are the only ones from which I have obtained identifiable fossils, but they seem to indicate the age of the series pretty clearly. Prof. Lapworth has determined the Graptolites, and Dr. Davidson the Brachiopoda.

Climacograptus antiquus?, *Lapw.*
—— bicornis?, *Hall.*
—— Scharenbergi, *Lapw.*
——, sp.
Cryptograptus tricornis, *Carr.*
Dicranograptus, sp.?
Diplograptus foliaceus, *Murch.*
—— rugosus, *Emm.*
Leptograptus flaccidus?, *Hall.*
Crinoids.
Beyrichia complicata, *Salt.*
Trinucleus concentricus, *Eaton.*
—— fimbriatus, *Murch.*
Lingula, sp.
Orthis testudinaria, *Dalm.*
Bellerophon bilobatus, *Sow.*

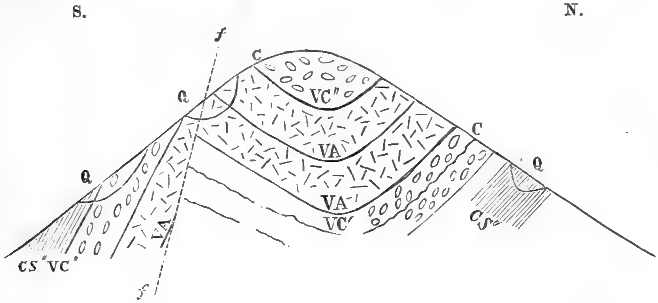
Orthis testudinaria, another *Orthis*, and crinoid stems have been obtained from the second locality just named in the south part of Bausley Hill *; while Mr. Morgan † has found *Thamniscus antiquus* amongst other forms in ashy beds to the N.E. of Middletown Hill. These fossils, of which some range from Lower to Middle Bala, some from Middle to Upper Bala, and some have a wider range, seem to indicate that these beds belong to the Bala group and are the equivalents of the top of the Glenkiln or bottom of the Hartfell series. Above them come similar unfossiliferous shales with more frequent grit bands. It is certainly likely that the exact equivalent of these beds may be found in the upper rocks of Hagley and Marrington in the Corndon district, but I am not yet sufficiently familiar with that area to speak with any certainty.

When traced to the S.W., ashy beds are intercalated between the conglomerates, and a fold and fault in the rocks makes them occupy a wide extent on the map. The structure of Middletown Hill is explained by the subjoined diagram (fig. 1), in which the fault at Middletown quarry is shown. The ash is made up of fragments of decomposed felspar, often replaced by kaolin, and stained light green, like some of the felspar crystals in weathered pieces of Shap-Fell granite: there are also flesh-coloured and black fragments, and fragments of banded volcanic rock. A large amount of this rock has been quarried for china-stone, but the depth of colour in all but a few beds spoiled it for this purpose. Under the microscope the ash shows all the characters of a trachytic tuff altered to

* Since this was written, Prof. Lapworth has found *Diplograptus foliaceus* in this locality, and *Trinucleus* in the matrix of the conglomerate.

† Quart. Journ. Geol. Soc. xli. 111.

Fig. 1.—*Section across Middletown Hill.* (Length, $\frac{1}{3}$ mile.)



C S′. Cambrian Shales. V C′. Lower Volcanic Conglomerate.
V A. Volcanic ash. V C″. Upper Volcanic Conglomerate.
C S″. Cambrian Shales. Q,=quarries. C. Little crags. *f f.* Fault.

kaolin and quartz. This ash is again seen to the S. of Moel-y-Golfa, and in one or two isolated spots to the N.E. It passes up into andesitic conglomerate, and that, in a quarry at the foot of the hill, into 10′ of volcanic grit without pebbles, followed by sandstone and shale with hard grit bands containing *Pentamerus*; a fault obscures the exact relations of the two groups.

The lowest beds seen in Moel-y-Golfa are lavas of an andesitic type, well exposed in the great crags at the S.W. end of the hill. Similar lavas are seen to succeed one another on the S.E. side, one of the lowest of them being amygdaloidal, to a total thickness perhaps of 400 feet, until, at about 650 feet from the summit, they are followed by ashy beds and these by conglomerates, both of which wrap round the S.W. end of the hill; these are visible in the crags and quarries on and near the Welshpool road. The ash, when not of the china-stone type, is obviously formed of the same materials as the lavas of the hill, and the conglomerates, in which I have measured fragments 2 feet long, are composed of lumps of the same rock.

The hill is very abrupt at its S.W. extremity, and the ashes and conglomerates do not thin out as they do northwards, but are replaced on the plain by the shales of Trewern, like those found elsewhere beneath the conglomerate, suggesting that the beds are cut off by a fault; but there is no additional evidence of this unless we consider the absence of the black grit of Belleisle Brook to be such.

At Cefn, near Buttington, there is an inlier, probably of the same rocks, associated with an intrusion of diabase. The quarries show shivery grey shales interbedded with grits often baked to quartzite and very much contorted by the intrusion *.

From this description it will be seen that the centre of volcanic activity was at Moel-y-Golfa, where the lavas occur and near to which the ash beds are thickest, while further north the area was for the most part submerged, becoming occasionally shallow for the formation of conglomerates and even at times upheaved to receive

* Silurian System, 292.

the ashes. Some bosses of rock on Moel-y-Golfa may be intrusive, but I have found no conclusive evidence of this; most of them are certainly lavas and have suffered denudation to form the conglomerates.

IV. Silurian Rocks (*Sedgwick*).

These occupy an area S.E. of the ridges, and closely overlap the Cambrian rocks, particularly on the flank of Middletown Hill, where the lowest beds are exposed. It is extremely unfortunate that, though these rocks are in close proximity to exposures of the volcanic conglomerate, the actual base and the character of the junction cannot be determined. The lower rocks, exposed in a lane leading from Middletown to the Barytes mine, consist of greenish-brown, rather tough, thin-bedded mudstones, and soft sandstone much stained with ochre and containing a few quartz pebbles and some hardened, impure siliceous concretions and beds; they are barren for the most part, but have yielded a few shell-casts. The strata dip at 35° S. 30° E., and about 250 feet are exposed. I have found the following fossils, most of which Dr. Davidson has kindly examined for me:—

Pentamerus globosus?, *Sow.*	Orthis rustica?, *Sow.*
—— oblongus, *Sow.*	——, sp.
—— undatus, *Sow.*	Leptæna transversalis, *Wahl.*
Athyris? sp.	Strophomena rhomboidalis, *Wahl*,

together with a Gasteropod and a small Brachiopod of an unknown genus, but resembling *Triplesia*. These fix the age of these beds as May-Hill, and so there must be a marked break between the Cambrian and Pentamerus-beds, and an unconformability of which the slight change in dip gives little evidence.

Faults which bear barytes traverse Middletown Hill to the N.E. of this exposure, coursing N. 35° W. and S. 35° E., and introduce a slip of similar rocks between the Cambrian rocks. In this strip I have found:—

Petraia subduplicata?, *M'Coy.*
Pentamerus oblongus, *Sow.*

There are no exposures to show what immediately follows these beds, but the next rock seen is a purple shale, shown in the small brooks near Middletown Schoolhouse and the New Inn, and in the brook which rises near the Four Crosses Inn. It is a purple shale, soft and micaceous, containing green bands and concretions. No fossils have hitherto been found in it. It dips S. 10° E. at from 35° to 50°, and appears to be about 200 feet thick, while the total thickness from the lowest May-Hill beds exposed to the top of this shale cannot be much less than 660 feet. The upper part becomes greyer and more concretionary till it passes into the ordinary grey Wenlock shale. The purple beds have also been recognized along the brooks and roads around the Buttington inlier, but I have not yet recognized Pentamerus-beds there. The position, appearance, and character of these shales link them with the purple shales above

Pentamerus-beds in Shropshire, and they are the probable equivalent of the Tarannon shales of North Wales.

The Wenlock shales follow, and they are of importance from their position as showing a transition from the calcareous development in Salop to the arenaceous type in Denbigh. They are admirably displayed in road- and railway-cuttings, small quarries, and a number of transverse streams which flow down from the Long Mountain. I have not yet been able to work out these rocks in great detail, still less to follow the zones to the S.E. side of the synclinal, but I hope at some future time to return to this, the abundance of Graptolites giving promise of useful results.

I have run four sections across these beds from N.W. to S.E., between the N. of the area and Buttington, and they show a pretty regular succession and palæontological development, such as enables us to compare them with other areas.

Beginning at the N. (fig. 2), a number of sections are laid open along the brook running from Hargrave Wood to Middletown. At the junction of this with a tributary flowing past the schoolhouse, the lowest beds of concretionary, grey, calcareous shale (*a*) contain a few undeterminable shells, and dip S. 15° E. at 32°. A little further up, where the brook crosses the railway, are similar shales (*b*) with concretions (2 feet across) dipping 10° S. 10° E., and containing the following Graptolites, which, together with others shortly to be mentioned, have been kindly determined by Prof. Lapworth :—

Cyrtograptus, sp.
Monograptus priodon, var. Flemingii, *Salt.*

These are Lower Wenlock forms. Further up, where a branch from Winnington Green enters, in a small quarry, are finer bedded shales (*c*) which dip S. 60° E. at 56°, and contain—

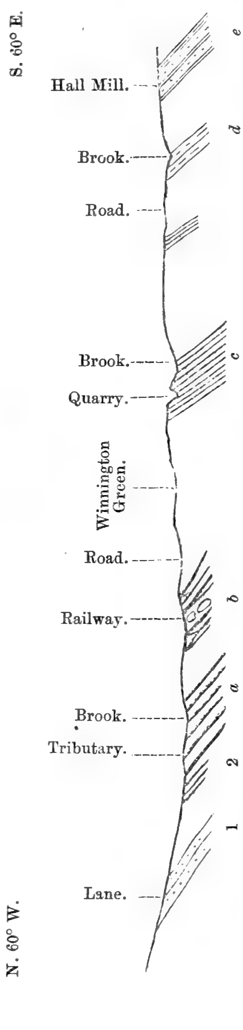


Fig. 2.—*Section from Middletown Hill to Purton Wood.* (Scale, 3 in. to a mile.)

1. Pentamerus-beds. 2. Purple shales. *a, b, c.* Wenlock beds. *d, e,* Ludlow beds.

Monograptus basilicus (dubius, *Süss*).
—— priodon, *Bronn.*
—— vomerinus ?, *Nich.*

Calymene, sp.
Cucullella, sp.
Orthoceras angulatum, *Hising.*,

all fossils belonging to the Upper Wenlock. Above this the beds get gradually more sandy and flaggy, as though the sea were slowly shallowing. Near the Rose and Crown Inn is a capital exposure in these upper beds (*d*), concretionary brown mudstones dipping 40° S. 20° E., and yielding :—

Monograptus colonus, *Lapw.*
—— leintwardinensis. *Hopk.*
Entomis tuberculosa, *Jones.*
Orthoceras, sp.

These fossils belong to the Lower Ludlow rocks, and must be classed with them. At the Hall Mill above this spot are brown and dark-grey sandy mudstones, finely laminated, with some calcareous bands (*e*) dipping 40° S. 25° E. Here I have found no fossils.

A second section runs from Coppice House, near Middletown Station, through Glyn to Trefnant, and shows a very similar succession. At Coppice House the grey shales dip 63° S. 20° E., and have yielded :—

Monograptus vomerinus, *Nich.*
Orthoceras subundulatum ?, *Portl.*

On the larger brook, where it receives tributaries from Glyn Common, massive concretionary shales are exposed in a quarry and have a slight dip to N.W. In these I have found :—

Monograptus colonus ?, *Lapw.*
—— Nilssoni, *Barr.*
—— priodon, var. Flemingii, *Salt.*
Orthoceras subundulatum ?, *Portl.*;

a very curious mixture of forms, of which the first ranges from Upper Wenlock to Lower Ludlow, the second belongs to the Upper Ludlow, and the third to Lower and Upper Wenlock. So these beds may come between Lower and Upper Wenlock. Half a mile further S.E., on the brook from Trefnant, are exposures of shales, with dips varying from S. 65° E. to S. 20° W. at low angles. Near to Trefnant these beds contain the following Lower Ludlow fossils :—

Monograptus Nilssoni, *Barr.*
—— Salweyi, *Hopk.*

A third section runs from Llwyn-Melyn farm past Dingle Mill to the County Bridge on the high road from Woolaston to Welshpool. In the lane from Trewern to Dingle Mill, and in the railway-cutting near Llwyn-Melyn, are the usual hard, grey, calcareous shales, very concretionary and dipping S. 20° W. at 38°. They contain—

Monograptus (like colonus, *Lapw.*)
Cardiola interrupta, *Brod.*
Orthoceras subundulatum, *Portl.*

Concretionary shales dip up Dingle Brook at 28° S. 5° E., and in

a quarry near the old mill, marked by an arrow on the Survey Map, I have obtained—

Monograptus colonus, *Lapw.*
Orthoceras, sp.

Above this are sandy laminated shales, exposed at the County Bridge, dipping 49° S. 10° E.

A fourth section goes S.E. from Sale, near Buttington, to Ucheldre, and shows purple shales at the base wrapping round the little anticlinal of Cambrian rock; these pass up by alternations into grey Wenlock shales, but all these rocks are much contorted near the Cambrian patch. Fossils are found in the Lower Wenlock of Sale—

Monograptus vomerinus, *Nich.*
Orthoceras subundulatum ?, *Port.*

Near Ucheldre a quarry with shale dipping 40° S. 20° E. yields—

Monograptus Rœmeri, *Barr.*;

and the neighbouring brook running to Lower Heldre, where it crosses the road, shows dark grey shales with—

Atrypa reticularis, *Linn.*
Rhynchonella nucula, *Sow.*
—— borealis, *Schloth.*

So we must class these beds with the Upper Wenlock.

Summing up the Silurian, there seem to be 5 zones:—

Valentian ...	1. Pentamerus Beds 2. Purple Shales	660′
Salopian	3. Lower Wenlock 4. Upper Wenlock 5. Lower Ludlow	about 2500′.

To zone 3 belong the beds with *Cyrtograpsus* (?), where Hargrave Brook crosses the railway, the beds of Coppice House and Sale. We must place between 3 and 4 the rocks of Glyn and Llwyn-Melyn. To 4 belong those of Winnington (*c*), Mill on Dingle Brook, and Ucheldre; and the beds of Trefnant and the Rose and Crown must be grouped in 5.

Although the Silurian usually dips at a lower angle than the Cambrian, particularly near the junction, the variation in dip is so great that we cannot use this as any proof of unconformability; but quite sufficient exists in the presence of bands containing Middle Bala and May-Hill fossils respectively, so near to one another as in the different exposures in Middletown Hill and to the south.

V. Igneous Rocks.

1. *Older Series.*

These occur in Moel-y-Golfa, and are for the most part well exposed on its crags. They appear to consist of a set of lavas belonging to an andesitic type, somewhat of the character of the andesites described by Mr. Teall in his paper on the Cheviot rocks*; but I think it highly probable that some of the steeper bosses of rock

* Geol. Mag. dec. ii. x. p. 100 *et seq.*

may be intrusive and take the place of the pipe of the old volcano. Of this, however, I have no further evidence than the sudden disappearance of the lava to the S.W. We might expect such rocks to be more highly crystalline than the others; but this need by no means necessarily be the case, for the amygdaloidal character of the more basic rocks, shortly to be described, shows that those parts at present exposed could not have been subjected to very great pressure, but probably cooled near the surface.

Macroscopically these rocks are dark grey or dull greenish in colour, weathering light brown or white, sharply jointed, sometimes columnar (as in the N.W. flank of the hill, where the columns are from 2 feet to 18 inches across) and often traversed by platy joints at right angles to the columns. They reveal a dead ground-mass with small porphyritic crystals of felspar—pink, white, or green, rarely more than ·1 inch in length—and black crystals of pyroxene, generally smaller; these are well shown on polished surfaces. Often the felspars look broken and rounded, and tempt one to think there may be ash-beds amongst the lavas; but though I have most carefully searched for such beds in the field and with the microscope, I have been unable to obtain conclusive evidence on this point, even the most fragmental-looking to the eye giving evidence under the microscope that they are merely lavas in which the crystals have been a little knocked about; and Prof. Bonney, who has most kindly examined several of my most typical specimens, entirely concurs in this conclusion. Microscopically, these rocks present only varietal differences, so that general descriptions will suffice.

1. *Felspar.* The smaller crystals have frequently perfect angles and edges; the larger are often broken or incomplete, at least at one end. There are generally two kinds present:—first, large crystals showing polysynthetic twinning; these are generally in the minority; but when this is the case the felspars have undergone much alteration, and this may have masked the twinning; secondly, singly twinned or untwinned crystals, sometimes quite like sanidine in their glassy clearness, cracks, and inclusions; but Prof. Bonney thinks these are generally plagioclase: probably both kinds are only labradorite. They are both much altered, chiefly to kaolin; and often this alteration following the almost rectangular cleavage-cracks, has isolated small spherules of unaltered mineral. Inclusions are very common, and usually the matter of the inclusions closely resembles the base of the rock; and even when it differs, it is seen to be only in a slightly different state of alteration, for transitions may be traced. In the specimen, which looks, when weathered, most like an ash (from the S.E. crags, 300 feet* from the summit), the inlets of the base are most obviously connected with growth; for from their shape they could not be accidental fractures, as a glance at fig. 4 will show. In a specimen taken at the northern end, 400 feet from the summit (fig. 3), Prof. Bonney noticed a little epidote and serpentinous aggregates enclosed in the felspar, and the latter are pretty common in other specimens.

* These, and the other distances given, express *vertical* height.

Fig. 3.—*Felspar-crystal in andesite at N. end of Moel-y-Golfa, 400 ft. from summit, showing fractures of crystal* (a) *and inclusion of serpentine* (b).

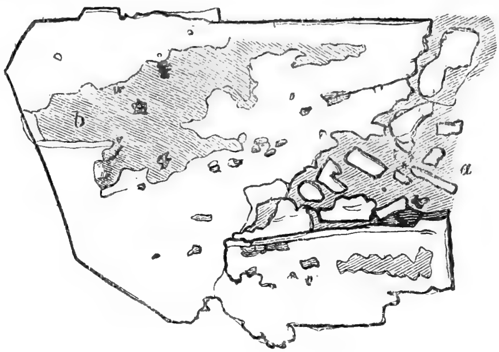


Fig. 4.—*Edge of felspar crystal showing inclusions of base.*

2. *Pyroxene.* There are two forms of this mineral present: (*a*) *Rhombic pyroxene*, in octagonal or elongated sections, indicating a good development of pinacoidal faces truncated by those of the prism. There is a good cleavage parallel to the best-developed pinacoid, but no trace of any other cleavage. The crystals are terminated by oblique faces, probably domes, which are generally only developed at one end of the crystal. The structure is slightly fibrous, and there are curious lamellæ of darker green mineral generally parallel to the principal pinacoid. It is slightly dichroic, passing from greenish yellow, when the cleavage is parallel to the short axis of the nicol, to light straw-yellow when placed at right angles. The maximum extinction takes place when the cleavage is parallel to one of the vibration-planes of the crossed nicols, and the polarization colours are not of a very high order. It occurs in crystals of all sizes, retaining its shape down to the smallest prisms. It is best observed in its unaltered state in the great crags running round the E. and S.E. side of the hill, at a vertical distance of from 300 to 400 feet from the summit, but in an altered state it occurs in almost all the lavas, being replaced by a green or brown serpentinous pseudomorph, in the manner so admirably figured by Mr. W. Cross*. The serpentine needles frequently have a radial arrangement, and there is more alteration in the large than in the smaller crystals.

* Bulletin, United States Geol. Surv. I. 1885, pl. ii. fig. 8.

In some of the specimens minute short needles of green mineral occur, arranged parallel to the pinacoid; in others they are longer and look more like distinct twins; exactly similar needles are frequently sown broadcast through the ground of the rock. They are somewhat opaque, and it is difficult to determine anything definite about them; they appear to be dichroic and to have a high extinction-angle, so they may possibly be an abnormal form of augite.

The hypersthene described by Mr. Whitman Cross * shows prismatic cleavage; that noticed by Mr. Teall from the Cheviots † appears to have no pinacoidal cleavage; the hypersthene in a Montserrat lava described by Mr. Waller ‡, too, shows prismatic as well as a brachypinacoidal cleavage; and all these are different in colour and in polarization-tints from the mineral here described. On the other hand the enstatite of Eycott Hill, described by Prof. Bonney §, is like this in shape, colour, cleavage, fibrous structure, and alteration, so that the mineral is some form of enstatite or bronzite. Prof. Rosenbusch too speaks of a similar mineral with pinacoidal cleavage.

(*b*) *Monoclinic pyroxene.* In the best-preserved specimens there is often sufficiently preserved to be recognizable a considerable quantity of augite, though the enstatite predominates over it. It is often altered to greenish chloritic products, and even further to calcite.

3. *Amphibole.* In one or two of the slides there is pretty characteristic brown dichroic hornblende, and in many of them are elongated and basal sections which, though very highly altered, must, from their outline, be referred to this mineral.

4. *Magnetite, Ilmenite, and Hæmatite,* are all of them present, the second probably in greatest quantity, in distinct crystals generally of a fair size though often in quite minute grains. Hæmatite is common in the felspars and pyroxenes where the rock is in an exposed situation, and tints the crystals and cracks with its characteristic colour.

5. *Black mica* has been suspected by Prof. Bonney in at least one of the slides, but it is evidently a rare accessory.

6. *Apatite* occurs, too, in several of the specimens, in clear elongated needles, and is evidently a product of early consolidation.

7. There are many alteration-products, mostly of a serpentinous nature, but some are clear and bright and colourless.

The ground-mass of the rock is a close felt of colourless microliths apparently of felspar; it breaks up into a pale mosaic between crossed nicols; amongst these are innumerable opaque, whitish and greenish bodies, whose presence renders it exceedingly difficult to say whether the base has any glass left in it. I have been unable, after the most minute search, to detect any unindividualized glass in the matrix, though in a few base inclusions in the felspar I think there

* W. Cross, *loc. cit.* p. 21.
† Teall, Geol. Mag. dec. ii. vol. x. p. 103.
‡ Waller, *ibid.* p. 291.
§ Bonney, Geol. Mag. dec. iii. vol. i. p. 77.

is a little still left. That it has once been a glass, I think, admits of little doubt. In some of the specimens were indications of flow-structure; out of this magma the pyroxenes appear to have crystallized first, and then the felspars. The average sp. gr. of the rocks is 2·66.

This description makes it pretty evident that we have here a group of andesites of that type becoming so widely known now as bearing rhombic pyroxene. This particular group appears to deserve the name of enstatite-andesites, or some might prefer to call them enstatite-porphyrites. Prof. Bonney says, "I could imagine some of the lavas I have from the Andes getting to look like this rock;" and the resemblance between their *structure* and that of the Rosenau andesites is most marked.

Most of them are undoubtedly lava-flows, and have been denuded to form conglomerates, the pebbles of which obviously consist of this rock, and the microscope completely confirms the identification. The ashy matter in which the pebbles are imbedded consists of broken crystals, like those in the andesite; and the Middletown ash might have been formed from such felspar crystals as occur in it. It is, as I have stated before, highly probable that some few of the bosses of rock may be intrusive. There are one or two small veins of it, too, intruded into the ash of Middletown quarry.

2. *Newer Series.*

Belan Bank, two hills N. and S. of the chapel at Bausley—the latter connected with Brimford Wood by dykes—Rodney's Pillar Hill, the Criggan, Foel Coppice, the Little Garreg near Trewern, a small rock near Cefn, at Buttington, and a small intrusion on Bulthey Hill, are all composed of varieties of intrusive igneous rock.

Macroscopically, it varies from dark grey rock, in which there are obvious crystals of pyroxene and felspar, to a green type, in which the crystals are less obvious and more decomposed. One rock in Brimford Wood contains a much elongated variety of augite and large felspars, so that it looks at first rather like a gabbro. Amygdaloids occur commonly, particularly at Rodney's Pillar Hill, and there are similar rocks right down to the base of the hill, which I examined in the company of Mr. Silvester and some others of my students; occasionally the vesicular structure is deceptive and due to the surface-weathering of some of the minerals; but in all the massifs some true amygdaloids can be found. The rock usually weathers brown, and is divided into large irregular columns on the summit of Rodney's Pillar Hill. The varieties group themselves under three main heads, so descriptions of specimens from a few typical localities will give the best idea of the structure of the rocks.

(*a*) Rodney's Pillar Hill, Criggan, Belan Bank, and Trewern. This type is green and shows lath-like felspars and pyroxene; it is granular in aspect, and there is not the obvious ground-mass of the andesites. It is often amygdaloidal, the kernels consisting of calcite. The rock is often ophitic in structure, but frequently there are spaces between the minerals occupied by opacite, apparently an

alteration-product. There are often two generations of felspar, larger lath-shaped porphyritic crystals and small microliths; both appear to be labradorite, though they are a good deal decomposed into greyish granular products: occasionally there are inclusions of serpentine in the felspar.

The *Pyroxene* is of two kinds. Colourless *augite* with marked cleavage- and growth-lines, often twinned, occurs in large and small irregular grains polarizing with bright colours and giving the usual high extinction-angle of augite; it fits in between the other constituents. Grains of *rhombic pyroxene* are also present in great quantity, though generally much decomposed; it is green, fibrous, and dichroic, changing from full green to light straw-yellow, and with one marked cleavage, so that it is the mineral that characterizes the andesites, namely, enstatite. It is altered generally into brownish fibrous matter, and still further into a mass of serpentine. The enstatite is present in much greater quantity than the augite.

Many scattered grains and crystals of *magnetite* and *ilmenite* are present, having evidently consolidated first, followed by the felspar, and that by pyroxenes, of which the enstatite probably solidified earlier than the augite. A highly altered form of this type presents the same characters, while the augite remains unaltered; the serpentinous products in shape and structure suggest the form of enstatite rather than that of olivine; opacite occupies the spaces between the crystals. A good deal of calcite is present in some of them, invading the serpentine first and then the felspar.

The average sp. gr. of the rock is 2·7. It must be called an enstatite-diabase or dolerite.

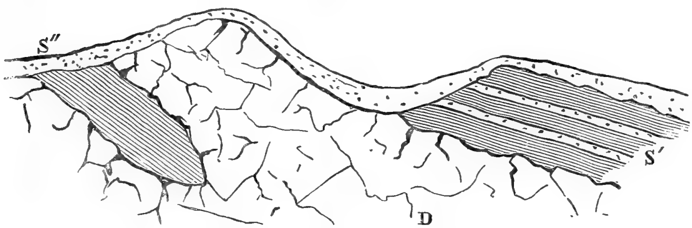
(*b*) Hills N. and S. of the Chapel in Bausley village. This is the dark-grey variety showing large distinctly twinned felspars and obvious pyroxene. It looks much like the Whin-Sill diabase, but the resemblance disappears under the microscope, which also reveals that a greater change has taken place in the rock than would be suspected. The structure of the rock is generally ophitic, the two principal ingredients being closely crystallized together; but occasionally there are felspar microliths or opacite between the crystals. There is an unusually large proportion of *plagioclase* in large crystals, but the pyroxene is almost unrecognizable; I think, however, I make out a little *augite*, and there are the usual serpentinous replacements which suggest the presence of *enstatite*, though often the grains are edged with calcite. The serpentine fibres are arranged in little radiating groups, and opaque whitish stuff often occurs between the crystals, probably an alteration-product. The sp. gr. of this rock is 2·697.

(*c*) A variety appears in Brimford Wood, apparently in segregation-veins, which is rather different from the other types. The structure is ophitic, large crystals of three minerals having formed together. The *felspar* is much decomposed, but is evidently plagioclase, the *augite* in large clear colourless crystals, and there is a serpentinous mineral in great quantity which might be a replacement of olivine or enstatite, but Prof. Bonney, who has seen the slide, thinks probably the former, and mentions rocks from North Wales rather like

this one. Where thrust in thin dykes into the shales, large felspars are still visible, but they are set in a microcrystalline matrix composed of small felspar crystals and calcite, which latter has taken the place of all but the felspar, and even attacked that. This rock is either an enstatite or olivine diabase.

These rocks are all intrusive into the Criggion shales surrounding them, and evidence of this is abundant throughout the district. On a small branch of Belleisle Brook the subjoined section (fig. 5) shows the

Fig. 5.—*Section in small tributary of Belleisle Brook.* (Length 15 feet.)



D. Diabase intrusive in shale, S′.
S″. Fragment of shale caught in diabase.

intrusion of diabase, and at least two other distinct veins of it have been found in other parts of this brook and its tributaries, connecting the Brimford Wood with the northern massifs. Then, again, the actual contact is seen to the west of the Criggan, where the diabase alters the shales very considerably at contact. A thin section of shale taken from this spot shows a development of small scales of white mica and of greenish brown dichroic mica parallel to the lamination; but the most interesting feature is the incipient brecciation of the rock by a number of minute faults evidently caused by the violence of intrusion. The faults vary in throw from ·2 to ·03 inch, and some of the very smallest may be as little as ·006 inch in throw; most of them are normal, but the largest and a few others are reversed—I count 14 of them in a specimen 2 inches long. On the S.E. side similar hardening takes place, the shales often being burnt red; but I cannot recognize any secondary crystallization. At Trewern and round Rodney's Pillar Hill the shales are also much contorted and hardened near the junction; in the quarry near Buttington station sand-beds are converted into quartzite.

As to the age of the diabases, we cannot do much more than conjecture. In no place do they actually traverse Silurian rocks, but near Buttington the later rocks are as remarkably disturbed as the Cambrian, and I trace this disturbance to the intrusion of igneous rock. If they are really post-Silurian it is very difficult to assign their exact age; for in this part of the country most of the post-Silurian igneous rocks are later than early Carboniferous, and are dolerites much less altered than these, and with a different mineral composition and structure. It is of course possible that they may belong to the

Old Red Sandstone period; but such rocks are absent from central England. There is one area which may afford some clue to this question, and that is the N.W. corner of the Corndon district, where similar diabases break through Cambrian and Silurian rocks. I have already begun to work there with the object of determining this point amongst others, but have not yet arrived at any sufficiently definite results.

Discussion.

Prof. T. Rupert Jones, while thanking the author of the paper, suggested that he should refer to the several groups of strata rather than use the names Cambrian and Silurian, the application of which is uncertain. Avoiding that subject, he wished to ask about the nodular trap-rock on the Shrewsbury road at the foot of the Breidden.

Mr. Cole had examined the Corndon masses and found a striking similarity between them and the rocks described by the author. He had himself found enstatite in the Corndon rocks, among which were probably some andesitic glasses.

Mr. Teall congratulated the author on his valuable paper. He would like to see some agreement as to the use of the terms andesite and porphyrite. Most of the so-called porphyrites that he had examined were merely altered andesites, and he was at present inclined to use the term in this sense. If this view were adopted, then the interbedded igneous rocks described by the author would have to be called porphyrites. This, however, was a very trivial criticism. The intrusive enstatite diabases were probably very similar in chemical composition to the altered andesites.

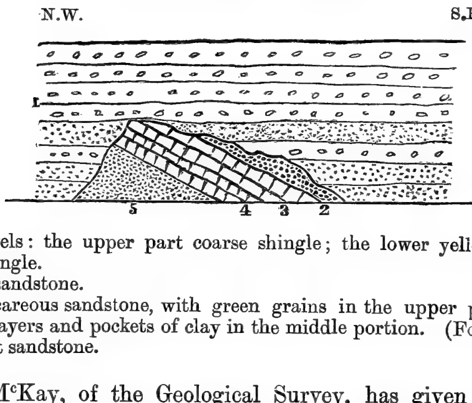
The Author said that he had endeavoured to avoid the difficulties about understanding the sense in which "Cambrian" and "Silurian" were employed, by using local names for the several rocks. He thought the term porphyrite might be restricted to certain classes of altered andesites.

41. *On the* CORRELATIONS *of the* "CURIOSITY-SHOP BED" *in* CANTERBURY, NEW ZEALAND. By Captain F. W. HUTTON, F.G.S. (Read June 24, 1885.)

THE River Rakaia, after leaving the mountains, flows in a south-east direction across the Canterbury Plains. In cutting its way down through the shingles and silts of these plains, it has come across and exposed on its left bank a small patch of calcareous and arenaceous rocks, which are so full of fossils as to have given the name "Curiosity-Shop" to the locality. It is situated between five and six miles below the bridge over the Rakaia Gorge.

I visited the Curiosity-Shop in February 1873, and made the accompanying section (fig. 1). All the exposed beds dip 20° E.S.E., and they appeared to me to belong to a single series.

Fig. 1.—*Curiosity-Shop on the left bank of the Rakaia River.*
(Length about 40 yards.)



1. River gravels: the upper part coarse shingle; the lower yellow sand and small shingle.
2. Grey soft sandstone.
3 and 4. Calcareous sandstone, with green grains in the upper part, with irregular layers and pockets of clay in the middle portion. (Fossils.)
5. Brown soft sandstone.

Mr. A. McKay, of the Geological Survey, has given a detailed description of these beds *, which I have embodied in the following Table:—

1. River-gravels.

Pareora Series.

2. Loose grey quartz sands, 15 feet thick, with a bed of badly preserved shells.

Upper Eocene Series.

3. Soft calcareous sandstone, 10 or 12 feet thick; in the upper part highly charged with glauconite; passing downwards into irregular beds of tufaceous clay.

* Reports of Geological Explorations, 1879–80, p. 77.

Cretaceo-Tertiary Series.

4. Calcareous sandstone without glauconite grains.

5. Loose grey or yellowish-brown sands; 35 feet thick.

Nos. 2 and 5 are much obscured by shingle-slips from the high river-bank.

The upper part of No. 3 is the principal horizon for fossils, although they are also found in No. 4. A list of the fossils obtained by Mr. McKay is given in his Report, in which he remarks that "all the shells and other fossils collected come from the highest of the upper calcareous rocks (No. 3). The overlying loose sands have been removed from an area some 30 feet in length by 10 feet broad, and on this surface a great number of the smaller shells &c. were picked up. Collecting these, I next turned over a considerable amount of the soft underlying rock, and in this I obtained many species, which, in weathering out, suffered so much damage that, as weathered specimens, they were not worth preserving. With the exception of *Lima lævigata*, the lower fossiliferous beds (No. 4) appear to differ mainly in the absence from them of many of the forms found in the higher beds; and the fossils in this lower part of the calcareous rocks being difficult of extraction, I contented myself with those more easily obtained from the higher beds" (*l. c.* p. 80). In the Canterbury Museum, however, there are specimens of *Lima lævigata* from the glauconitic limestone (No. 3), and so it seems that No. 4 has not a single fossil which is not found in No. 3. Consequently there can be no palæontological reason for putting these beds into different systems.

Mr. McKay's reasons for dividing the beds are the following:—He considers the lower sands (No. 5), from their appearance, to be the same as certain sands in the Malvern Hills, which are striking in the direction of the Curiosity-Shop, but are some four or five miles distant. These sands in the Malvern Hills form the upper part of the coal-measures, and are generally acknowledged to belong to the Waipara System. Mr. McKay then points out that the sands in the Malvern Hills are covered by anamesites, which, according to Dr. von Haast, are identical with anamesites interbedded with the "Weka-pass limestone" at Timaru, 60 miles to the south. "With this," he says, "the unavoidable conclusion as far as the sandy beds are concerned, I cannot but agree, and am therefore bound to consider the lower sands at the Curiosity-Shop as belonging to some part of the Cretaceo-Tertiary series" (*l. c.* p. 78). The upper calcareous bed (No. 3) he considers, from its fossils, "to belong to the 'Hutchinson's-Quarry beds,' or the Mount-Brown limestone, the higher beds of the section being referred to the Pareora formation, which everywhere succeeds with apparent conformity." And so he advances to this conclusion:—"There is a necessity for having an unconformity somewhere in this section, since it cannot be supposed, with the evidence to the contrary which has already been adduced, that the Pareora beds are conformable

to the lower beds of the Cretaceo-Tertiary series †. It remains, therefore, that the unconformity must be placed either below the limestones and calcareous greensands altogether, or—where I incline to put it—between the upper and lower parts of this division." Accordingly in his section he shows No. 3 quite unconformable to No. 4.

I have given Mr. McKay's argument as fairly as I can; but it will be unnecessary to criticise it, although it is favourably noticed by Dr. Hector (*l. c.* p. xvii). I have mentioned it to show how slight is the foundation for introducing an unconformity into this section, which is published by the Survey, and reproduced by Dr. Hector in his Progress Report. As the fossiliferous bed, No. 3, is allowed by Mr. McKay and by Dr. Hector ('Geological Reports,' 1883–4, p. xiii) to belong to the Oamaru series, it does not matter for my present argument what age the underlying beds are supposed to be of. My object is to attempt to correlate bed No. 3 with other rocks in Canterbury and Otago. Through the kindness of Dr. von Haast, I have been allowed to examine all the Tertiary New Zealand fossils in the Canterbury Museum, and consequently I am in a position to make a more complete list of the Curiosity-Shop fossils than has hitherto been given, and to add several species to the list from the Weka-pass stone. Dr. Hector has also allowed me to examine the Ototara fossils in the Wellington Museum, so that I can now give a tolerably correct list of them also.

List of Fossils from the Curiosity-Shop.

* Species marked with an asterisk are also found in rocks recognized as Cretaceo-Tertiary by Dr. Hector in Geol. Reports, 1881, p. 118, xc.–vi. *b*.

Vertebrata.

*Palæeudyptes antarcticus, Huxley, Quart. Journ. Geol. Soc. 1859, p. 670.

These specimens have been determined by Dr. Hector (Geol. Reports, 1879–80, p. xvi); also found in the Ototara building-stone; at Brighton on the west coast; and at the horizon of the Weka-pass stone at Amuri Bluff.

*Carcharodon angustidens, Agassiz, Poiss. Foss. vol. 3.

Found also in the Weka-pass stone; in the Waihao limestone; and in the neighbourhood of Oamaru, the exact locality not known.

Mollusca.

Siphonalia dilatata, Quoy and Gaimard (*Fusus*), Voy. 'Astrolabe,' Zool. ii. p. 498, pl. 34, f. 15, 16.

Reported by Mr. McKay. I have seen no specimens. This species is still living, and extends through the Wanganui and Pareora systems.

† *Op. cit.* p. 80.

*Ancillaria australis, Sow.; Reeve, Conch. Icon. f. 7.

Reported by Mr. M^cKay. I have seen no specimens. This species is still living, and extends through the Wanganui and Pareora systems. According to Mr. M^cKay it is also found in the Cretaceo-Tertiary beds at Trelissic Basin (Geol. Reports, 1879–80, p. 70).

*Voluta pacifica, Lamarck; Quoy and Gaimard, Voy. 'Astrolabe,' Zool. ii. p. 625, pl. 44, f. 6.

Reported by Mr. M^cKay. I have seen no specimens. This species is still living, and extends through the Wanganui, the Pareora, and the Oamuru systems. It is also found in the Weka-pass stone, in the Ototara limestone, and at Caversham, in rocks considered as Cretaceo-Tertiary by Dr. Hector.

*Marginella dubia, Hutton, Cat. Tertiary Moll. of N. Z. 1873, p. 8.

Reported by Mr. M^cKay. Also found in the Cretaceo-Tertiary rocks of Trelissic Basin (*l. c.* p. 70).

*Cassis senex, Hutton. Cat. Tertiary Moll. of N. Z. 1873, p. 11 (*Struthiolaria*).

Better specimens have enabled me to refer this shell to its true genus. It is also found at Caversham and in the Weka-pass stone; also in the Hutchinson's-Quarry beds at Oamaru; and in the Pareora system at Pareora.

Natica solida, Sow. in Darwin's Geol. Obs. in S. America, p. 225.

Found commonly in the Pareora system; in the Otakaika limestone, and, according to Mr. M^cKay, in the Upper Eocene, and doubtfully in the Cretaceo-Tertiary rocks of Trelissic Basin.

I doubt this being Sowerby's species.

*Turritella gigantea, Hutton, Cat. Tertiary Moll. of N. Z. 1873, p. 12.

Reported by Mr. M^cKay. It is also found at Caversham, and in the Pareora system at Pareora.

*Scalaria lyrata, Zittel, Reise der 'Novara,' Geol. ii. p. 41.

Also found in the Weka-pass stone; in the Ototara stone; at Aotea, and at Port Waikato. I do not see how this species is to be distinguished from *S. rugulosa*, Sow., from Chili.

*Scalaria Browni, Zittel, *l. c.* p. 42.

Found also at Brighton on the west coast; at Aotea; and in the Pareora system at White-Rock River. No doubt it is a variety of the last species.

Scalaria marginata, Hutton, Trans. N. Z. Institute, vol. xvii. 1885.

A well-marked species that has not been found elsewhere.

*TROCHILA NEOZELANICA, Lesson, Voy. 'Coquille,' Zool. ii. p. 395.

T. maculata, Reeve, Conch. Icon. f. 15.

Reported by Mr. McKay. This species is still living, and extends through the Wanganui and Pareora systems; and, according to Mr. McKay, is also found in the Cretaceo-Tertiary rock of Trelissic Basin.

DENTALIUM GIGANTEUM, Hutton, Cat. Tertiary Moll. of N. Z. 1873, p. 2.

Reported by Mr. McKay. Found also in other places in the Oamaru and Pareora systems.

*TEREDO (?) HEAPHYI, Zittel, Reise der 'Novara,' Geol. ii. p. 45, taf. xiv. f. 4.

Cladopora directa, Hutton, Trans. N. Z. Inst. vol. ix. p. 597.

Also occurs in the Waihao greensands, and at other places in the Oamuru and Pareora systems.

*PANOPÆA ORBITA, Hutton.

P. plicata, Hutton, Cat. Tertiary Moll. of N. Z. 1873, p. 17 (not of Sowerby).

Reported by Mr. McKay. Found also at Raglan, and in several localities in the Pareora system. According to Mr. McKay it occurs in the Upper Eocene and Cretaceo-Tertiary rocks in Trelissic Basin.

LUCINA DENTATA, Wood, Gen. Conch. p. 195, pl. 46. f. 7.

Reported by Mr. McKay. This species is still living, and extends through the Wanganui, Pareora, and Oamaru systems.

MYSIA GLOBULARIS, Lamarck, Anim. sans Vert. vi. p. 231.

Reported by Mr. McKay. This species is still living, and has not been found elsewhere in rocks older than the Wanganui system.

CRASSATELLA OBESA, Adams, Proc. Zool. Soc. 1852, p. 90.

C. Trailli, Hutton, Cat. Tertiary Moll. of N. Z. p. 24.

This species is still living, but has only been found in rocks belonging to the Pareora system.

*CUCULLÆA ALTA, Sow. in Darwin's Geol. Obs. in S. America, p. 252.

Found also at Kakanui and Raglan, and in many places in the Pareora system.

*PECTEN WILLIAMSONI, Zittel, Reise der 'Novara,' Geol. ii. p. 50, pl. ix. f. 11.

Found also in the Weka-pass stone, at Aotea, Raglan, and on the coast south of Port Waikato. This may be the *P. gemmulatus*, Reeve, mentioned by Mr. McKay.

*PECTEN CHATHAMENSIS, Hutton, Cat. Tertiary Moll. of N. Z. p. 29.

Reported by Mr. McKay. Found also on the east coast of Wellington, in Pareora rocks; and according to Mr. McKay, in the Upper Eocene and Cretaceo-Tertiary rocks of the Trelissic Basin.

*PECTEN HOCHSTETTERI, Zittel, Reise der 'Novara,' Geol. ii. p. 50, pl. xi. f. 5 *a*.

Found also in the Weka-pass stone; in the Ototara stone; at Caversham; Point Elizabeth; Aotea; Raglan, and coast to the north. Also in the Pareora system at Waikari and Motanau.

*PECTEN HUTCHINSONI, Hutton, Cat. Tertiary Moll. of N. Z. p. 31.

Found also in the Weka-pass stone; at Kakanui, and in several places in rocks belonging to the Oamaru system. Also, according to Mr. McKay, in the Upper Eocene and Cretaceo-Tertiary rocks in the Trelissic Basin.

*LIMA LÆVIGATA, Hutton, *op. cit.* p. 33.

Reported by Mr. McKay. Found also in the Cobden limestone; at Waihola gorge in Otago; at the Heathstock-Road Quarry in the Weka-pass stone; and in the Mount-Somers building-stone.

LIMA PAUCISULCATA, Hutton, *op. cit.* p. 33.

Reported by Mr. McKay. Found also at Cape Farewell.

LIMA PALEATA, *op. cit.* p. 33.

Found also in the Ototara stone, and the Mount-Somers building-stone.

LIMA MULTIRADIATA, *op. cit.* p. 33.

Probably a variety of the last. Not known elsewhere.

LIMA CRASSA (?), Hutton, *op. cit.* p. 33.

Reported doubtfully by Mr. McKay. This species is perhaps the same as the recent *L. neozelandica*, Sow. (P. Z. S. 1876, p. 754). It is found in several localities in the Pareora system.

BRACHIOPODA.

TEREBRATULA ALDINGÆ, Tate, Trans. Phil. Soc. of Adelaide, 1880, p. 5, pl. x. f. 2.

Not known from any other locality in New Zealand.

*WALDHEIMIA LENTICULARIS, Deshayes, Mag. Zool. 1841, t. 41.

A living species extending through the Wanganui, Pareora, and Oamuru systems. Found also in the Weka-pass stone, and in the Waihao limestone.

*WALDHEIMIA TRIANGULARIS, Hutton, Cat. Tertiary Moll. of N. Z. p. 36.

Reported by Mr. McKay. Found also in the Weka-pass stone, and in various places in the Oamaru and Pareora systems.

*WALDHEIMIA PATAGONICA, Sow. in Darwin's Geol. Obs. in S. America, p. 252.

Found also in the Cobden limestone, and in various places in the Oamaru and Pareora systems.

*?TEREBRATELLA SINUATA, Hutton, Cat. Tertiary Moll. of N. Z. p. 36.

Found also in the lower beds in the Trelissic Basin, and the Upper Eocene beds at Oamaru.

*TEREBRATELLA GAULTERI, Morris, Quart. Journ. Geol. Soc. 1850, vi. p. 329.

Found also in the Ototara stone, and at Raglan.

*TEREBRATELLA SUESSI, Hutton, Cat. Tertiary Moll. of N. Z. p. 37.

Terebratella, sp., Süss, Reise der 'Novara,' Geol. ii. p. 57, taf. ix. f. 6.

Found also in the Cretaceo-Tertiary rocks of the Trelissic Basin (McKay).

TEREBRATELLA FURCULIFERA (?), Tate, Trans. Phil. Soc. of Adelaide, 1880, p. 22, pl. xi. f. 7.

Not known elsewhere in New Zealand.

RHYNCHONELLA NIGRICANS, Sow. Thes. Conch. i. p. 342.

A still living species extending through the Wanganui, Pareora, and Oamaru systems.

*RHYNCHONELLA SQUAMOSA, Hutton, Cat. Tertiary Moll. of N. Z. p. 37; Tate, *l. c.* pl. ix. f. 9.

R. nigricans, var. *pyxidata*, Davidson, Voyage of the 'Challenger,' Zool. i. p. 59.

A living species found also in the Cretaceo-Tertiary rocks of the Trelissic Basin (McKay).

ECHINODERMATA.

PENTACRINUS STELLATUS, Hutton, Cat. Tertiary Moll. & Echin. of N. Z. 1873, p. 38.

Found also at the Chatham Islands.

*CIDARIS STRIATA, Hutton, *l. c.* p. 38.

Found also at Brighton on the west coast.

*ECHINUS ENYSII, Hutton, *l. c.* p. 39.

Also found, according to Mr. McKay, in the Upper Eocene and Cretaceo-Tertiary rocks of Trelissic Basin.

LOVENIA FORMOSA, Zittel, Reise der 'Novara,' Geol. ii. p. 63, pl. xii. f. 2.

Also found in several localities in Upper Eocene rocks. Probably not specifically distinct from *L. tuberculata* and *L. Forbesii.*

HEMIASTER (?) POSITUS, Hutton, *l. c.* p. 42.

Not known from any other locality.

*MEOMA (?) CRAWFORDI, Hutton, *l. c.* p. 42.

Also found in the Weka-pass stone; the Ototara stone; Caversham; Maerewhenua limestone, and many other places. Much like *Megalaster compressus*, Duncan (Quart. Journ. Geol. Soc. 1877, xxxiii. p. 61), which is the same as *Pericosmus compressus* of M^cCoy.

MEOMA (?) TUBERCULATA, Hutton, *l. c.* p. 43.

Reported by Mr. M^cKay. Also found in the Upper Eocene beds at Trelissic Basin.

BRYOZOA.

SELENARIA HEMISPHÆRICA, Busk, MS. (?).

Woods, Geol. Obs. in S. Australia, p. 73, pl. 'Fossil Bryozoa,' f. 3. Referred with doubt, as no specimens have been compared. Our species is also found in the Upper Eocene rocks of Mount Brown.

CŒLENTERATA.

*GRAPHULARIA (?) SENESCENS, Tate, Quart. Journ. Geol. Soc. vol. xxxiii. p. 257.

Found also in the limestones of Otakaika, Maerewhenua, and Waihao. Identified by Dr. Hector after comparison with S. Australian specimens (Geol. Reports, 1881, p. xxix); he considers them, however, to be spines of *Cidaris*.

This list contains 48 species, of which 29 or 30, including both the vertebrates, are also found in rocks regarded as Cretaceo-Tertiary by the Geological Survey. Also 22 species are found in the Pareora system or later, of which 14 are also found in the Cretaceo-Tertiary series. There are 10 or 11 species not found either in the Cretaceo-Tertiary or in the Pareora. The Curiosity-Shop beds are therefore more closely related palæontologically to the Cretaceo-Tertiary than to the Pareora, while the number of peculiar species is not sufficient to make them stand separately as an Upper Eocene system. I will now, therefore, take some other localities of Cretaceo-Tertiary rocks for comparison.

LIST OF FOSSILS FROM THE WEKA-PASS STONE, NORTH CANTERBURY.

* Species marked with an asterisk are also found in the Curiosity-Shop beds, or in acknowledged Upper Eocene rocks, or younger.

VERTEBRATA.

CETACEAN BONES.

*PALÆEUDYPTES ANTARCTICUS, Huxley. At Amuri Bluff.

*CARCHARODON ANGUSTIDENS, Ag.

MOLLUSCA.

ATURIA ZICZAC, var. AUSTRALIS, M^cCoy, Prodr. Palæont. Victoria, Decade ii. p. 21, pl. xxiv.

Found also in the Kakanui limestone, and at Waihemo in the Shag Valley, Otago.

*VOLUTA PACIFICA, Lamarck.

Var. *elongata*, Swainson.

*VOLUTA ATTENUATA, Hutton.

V. elongata, Hutton, Cat. Tertiary Moll. of N. Z. 1873, p. 7 (not of Swainson).

Found also in the Pareora system at Pareora, and, according to Mr. McKay, in the Cretaceo-Tertiary series at Trelissic Basin.

*CASSIS SENEX, Hutton.

SCALARIA ROTUNDA, Hutton, Cat. Tertiary Moll. of N. Z. 1873, p. 10.

Found also at Brighton, on the West Coast, associated with bones of *Palæeudyptes antarcticus* and Turtle.

*SCALARIA LYRATA, Zittel.

*PLEUROTOMARIA TERTIARIA, McCoy, Prodr. Palæont. Vict., Decade iii. p. 23, pl. xxv. f. 1.

Found also in the Ototara stone, and in the Upper Eocene limestone of Mt. Somers.

*PECTEN WILLIAMSONI, Zittel.

*PECTEN FISCHERI, Zittel, Reise der 'Novara,' Geol. ii. p. 53, pl. ix. f. 1, 2.

Found also in the Ototara stone, and, according to Mr. McKay, in the Upper Eocene rocks of Trelissic Basin.

*PECTEN HUTCHINSONI, Hutton.

PECTEN BEETHAMI, var. *β*, Hutton, Cat. Tertiary Moll. of N. Z. p. 32.

Found also near Caversham, near Dunedin.

*PECTEN HOCHSTETTERI, Zittel.

*LIMA LÆVIGATA, Hutton.

BRACHIOPODA.

*TEREBRATULA (?) BULBOSA, Tate, Trans. Phil. Soc. of Adelaide, 1880, p. 6, pl. vii. f. 5.

Waldheimia concentrica, Hutton, *l. c.* p. 35.

Reported by Mr. McKay from the Upper Eocene and Cretaceo-Tertiary rocks of Trelissic Basin.

*WALDHEIMIA LENTICULARIS, Deshayes.

*WALDHEIMIA TRIANGULARIS, Hutton.

WALDHEIMIA TAYLORI, Etheridge, Ann. & Mag. Nat. Hist. 1876, vol. xvii. p. 18, pl. i. f. 3; Tate, *l. c.* pl. xi. f. 2.

ECHINODERMATA.

*MEOMA (?) CRAWFORDI, Hutton.

MEOMA (?) BREVIPETALATA, Hutton, Cat. Tertiary Moll. and Echin. of N. Z. p. 43.

Found also in the Cobden limestone.

*SCHIZASTER ROTUNDATUS, Zittel, Reise der 'Novara,' Geol. ii. p. 64, taf. xi. f. 1.

Found also in Upper Eocene rocks at Cape Farewell and Oamaru. Also at Aotea and Port Waikato.

CŒLENTERATA.

SPHENOTROCHUS HUTTONIANUS, Tenison-Woods, Palæont. of N. Z. pt. iv. Corals and Bryozoa, 1880, p. 10, f. 9.

*FLABELLUM RADIANS, Ten.-Woods, *l.c.* p. 14, f. 13.

Found also in the Upper Eocene rocks at Oamaru.

*FLABELLUM CIRCULARE, Ten.-Woods, *l. c.* p. 12, f. 7.

Found also at Wanganui.

Of these 26 species, 12 (including 2 vertebrates) occur in the Curiosity-Shop beds, and 8 others are found in other places in New Zealand in rocks of Upper Eocene age or younger. Of the remaining six, two are Miocene fossils in Australia. I cannot therefore hesitate in putting the Weka-pass stone into the same system as the Curiosity-Shop beds. It must also be noticed that *Pecten Zittelli*, Hutton (Cat. Tert. Moll. N. Z. p. 32), occurs in the "Grey Marl" above the Weka-pass stone †, which must also be referred to the same series.

LIST OF THE OTOTARA FOSSILS FROM OAMARU.

* Species marked with an asterisk are also found in the Curiosity-Shop beds, or the Weka-pass stone, or in younger rocks.

VERTEBRATA.

*PALÆEUDYPTES ANTARCTICUS, var. AUSTRALIS, Huxley.

In the Ototara limestone.

MOLLUSCA.

*ATURIA ZICZAC, var. AUSTRALIS, McCoy.

In the Kakanui limestone.

† Quart. Journ. Geol. Soc. vol. xli. p. 274, and Cat. Colonial Museum, Wellington, 1870, p. 190 (*Pecten pleuronectes*).

*VOLUTA PACIFICA, var. ELONGATA, Swainson.

In the Ototara limestone.

*SCALARIA LYRATA, Zittel.

In the Ototara limestone.

*PLEUROTOMARIA TERTIARIA, McCoy.

In the Ototara limestone of Cave Valley.

*DENTALIUM MANTELLI, Zittel, Reise der 'Novara,' Geol. ii. p. 45.

D. irregulare, Hutton, *l. c.* p. 1.

At Mahemo. Found elsewhere only in the Pareora system.

*CUCULLÆA ALTA, Sowerby.

In Volcanic tuff at Kakanui.

*PECTEN HOCHSTETTERI, Zittel.

In the Ototara limestone.

*PECTEN FISCHERI, Zittel.

In the Ototara limestone at Cave Valley.

*PECTEN HECTORI, Hutton, Cat. Tertiary Moll. of N. Z. p. 30.

In the Kakanui limestone; also at Brighton; and according to Mr. McKay, in the Upper Eocene rocks at Trelissic Basin.

*PECTEN HUTCHINSONI, Hutton.

In the Kakanui limestone, and the volcanic tuff at Kakanui.

*PECTEN CRAWFORDI, Hutton, Cat. Tertiary Moll. of N. Z. p. 32.

In the volcanic tuff at Kakanui. Found also in the Pareora system.

PECTEN, sp. ind.

Maheno.

*PECTEN POLYMORPHOIDES, Zittel, Reise der 'Novara,' Geol. ii. p. 51, pl. xi. f. 3.

In volcanic tuff at Kakanui; also, according to Mr. McKay, in the Upper Eocene rocks at Trelissic Basin.

*LIMA PALEATA, Hutton.

In the Ototara limestone.

BRACHIOPODA.

WALDHEIMIA GRAVIDA, Süss, Reise der 'Novara,' Geol. ii. p. 56, pl. ix. f. 5.

In the Kakanui limestone.

*Waldheimia sufflata, Tate, Trans. Phil. Soc. of Adelaide, 1880, p. 18, pl. viii. f. 4.

In the Kakanui limestone. Found also in the Pareora and Wanganui systems.

*Terebratella Gaulteri, Morris.

In the Ototara limestone at Cave Valley.

Magasella Woodsii, Tate, Trans. Phil. Soc. Adelaide, 1880, p. 24, pl. x. f. 3.

Waldheimia tapirina, Hutton, *l. c.* p. 36.

In the Ototara limestone at Cave Valley. Also in the Cobden limestone.

Echinodermata.

Macropneustes (?) spatangiformis, Hutton, Cat. Tertiary Moll. and Echin. of N. Z. p. 40.

In the Ototara limestone; also in the Cobden limestone.

*Meoma (?) Crawfordi, Hutton.

In the Ototara limestone.

Here again we have 21 species, of which 11, including *Palæeudyptes*, are found in the Curiosity-Shop or the Weka-pass stone; and of the others, six are found in the Upper Eocene or younger deposits, leaving only four as possible Cretaceo-Tertiary forms, and these, it must be remembered, are not identical with any Waipara fossils.

Valley of the Waitaki.

Although I am unable to give anything like a complete list of the fossils found in the Valley of the Waitaki, the district is too important to be passed over. The following are mentioned by Dr. Hector and by Mr. McKay as occurring in rocks belonging to the Cretaceo-Tertiary series (Rep. Geol. Expl. 1881). I have also added four others from the Waihao limestone in the Canterbury Museum.

Maerewhenua Limestone.

Kekenodon onamata, *Hector*, Trans. N. Z. Inst. vol. xiii. p. 435, pl. xviii. (1881).
Cetacean bones, in the lower part.
Pecten Hochstetteri, *Zittel.*
Meoma (?) Crawfordi, *Hutton.*
Graphularia (?) senescens, *Tate.*
Flabellum circulare, *Ten.-Woods.*

In 1880 Mr. McKay stated that the beds overlying the Maerewhenua limestone must be referred to the Cretaceo-Tertiary series from "the character of a majority of the fossils found in them" (Geol. Rep. 1881, p. 69); but the next year he referred this limestone with the overlying beds to the Upper Eocene, also on account of the fossils found in them (*l. c.* p. 103). Certainly there is no palæontological reason for separating this limestone from the Wekapass stone and the Curiosity-Shop beds.

Waihao Limestone.

Carcharodon angustidens, *Ag.*
Waldheimia lenticularis, *Deshayes.*
Eupatagus Grayi, *Hutton, l. c.* p. 41; also found in the Cobden limestone.
Macropneustes (?) spatangiformis, *Hutton.*
Graphularia (?) senescens, *Tate.*

In "Chalk-marls" below the limestone are the following:—

Pecten Zittelli, *Hutton.*
Sphenotrochus Huttonianus, *Tenison-Woods.*

Here the Echinoderms are different from those of the Curiosity Shop and Weka pass, but one of them is found in the Ototara limestone; and, as the beds are underlain by rocks containing the *Pecten Zittelli* and *Sphenotrochus Huttonianus* of the Weka-pass stone, they cannot be looked upon as indicating a greater age.

In Marly Greensands below the Limestones.

At Maerewhenua:—

Cetacean bones.

At Wharekauri:—

Nautilus danicus, *D'Orb.* (?)*
Harpactocarcinus tumidus, *H. Woodward,* Quart. Journ. Geol. Soc. vol. xxxii. p. 71; found also at Brighton, and at Double Corner, N. Canterbury.

At Waihao:—

Aturia ziczac, var. australis, *M^c Coy.*
Pleurotoma, sp., like Pareora forms.
Limopsis, sp., like *P. aurita,* an Upper Eocene and Miocene form.

Here we have certainly a Cretaceous species in *Nautilus danicus,* but it is doubtfully identified by Mr. McKay, and is probably the ventricose form of *A. ziczac.*

In the Island Sandstone at Black Point.

Ancyloceras (?), sp., *Hector,* Geol. Rep. 1876-7, p. x.
Baculites (?), sp., *Hector, l. c.*
Belemnites (?), sp., *Hector, l. c.*

Here also we get Cretaceous Cephalopoda, but all are doubtfully determined. Mr. McKay kindly showed me these fossils in the Wellington Museum. There is, I believe, but one form. It is a small, delicate, straight shell, slightly tapering, with rather close, well-marked, transverse ribs (like *Tentaculites*). It looks like a Cephalopod, but no section has been made. The siphon is said to be marginal; but it is obscure, and I could not satisfy myself of its presence. There is no external appearance of lobed or foliated septa.

* Mr. McKay informs me that this is the same as his so-called Ammonite from near Greymouth, Geol. Rep. 1873-4, p. 81.

It cannot be *Ancyloceras*, because the ribs are of equal strength all round; and it cannot be *Baculites*, because the ribs are quite transverse. If it be a Cephalopod at all, it must, I think, be a new genus. and consequently it has but little chronological value.

Evidently, if we can trust to palæontological evidence, the Ototara series, both at Oamaru and in the Waitaki Valley, together with the Weka-pass stone, must be included in one system with the Curiosity-Shop beds. Mr. McKay certainly says of the fossils of the Cretaceo-Tertiary series that "in all cases these are specifically different from the shells found in the higher parts of the series, which are mainly the fossils of Professor Hutton's Oamaru formation" (Geol. Rep. 1883–4, p. 59); but, as he gives no name, it is impossible to attempt to reconcile his statement with my list, and it is opposed to his own list of the fossils of the Trelissic Basin (Geol. Rep. 1879–80, p. 70), where about one fifth are common to both series.

But Dr. Hector does not rely altogether on palæontological evidence for separating his Upper Eocene rocks from the upper part of his Cretaceo-Tertiary series; he considers that an unconformity exists between them. I have already shown that no unconformity exists in the Weka-pass district *. I will now take the north of Otago, a district which I examined in December 1873.

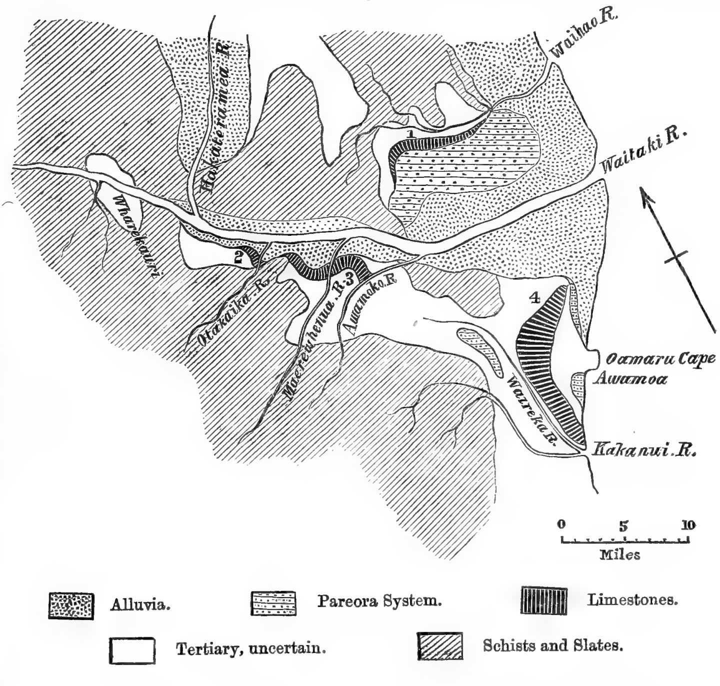
Dr. Hector says, "These higher [Upper Eocene] beds it has been impossible to separate, either stratigraphically or otherwise, from the Awamoa series [Pareora beds], which overlie them; whilst between this and the underlying Cretaceo-Tertiary series unconformity is to be observed at several points, as in the Cape Hills [Oamaru], and at Cape Campbell (*vide* Report on that district), although it may be doubted whether the Awatere beds, which there rest unconformably on the Cretaceo-Tertiary series, are the true equivalents of the Awamoa beds, or of Upper Miocene age. Apart from this, however, the character of the volcanic rocks at Oamaru, as evidencing the existence of a land-surface, together with their superior position to those of the calcareous beds of Hutchinson's quarry, with the Awamoa beds resting conformably on them in Lime-kiln Gully, sufficiently attest the unconformity, which is further supported by the occurrence of an outlier of Awamoa beds resting upon the greensands and coal-grits in the Waireka Valley"†. This argument may be summed up as follows:—The volcanic rocks at Oamaru Cape prove a land-surface; consequently the Hutchinson's-quarry beds which lie above the volcanic rocks must be unconformable to the Cretaceo-Tertiary which lie below them. Further, no unconformity can be made out between the Hutchinson's-quarry beds and the overlying Awamoa series (Pareora system); but at Cape Campbell (300 miles away) beds belonging to the Pareora system (Awatere series) are unconformable to the Cretaceo-Tertiary; it may, however, be doubted

* "On the Geological position of the Weka-pass Stone," Quart. Journ. Geol. c. vol. xli. p. 266.

† Report of Geological Explorations, 1876–7, p. ix.

whether the Awatere series is the equivalent of the Awamoa series. Now neither Dr. Hector nor Mr. McKay gives any proof of this land-surface; but Mr. McKay told me that his reason for assuming its existence was the scoriaceous nature of some of the rocks, which is quite insufficient. Also I fail to see in Mr. McKay's Report any evidence at all of an unconformity. He certainly gives a section (No. 3) showing an unconformity; but there must be some mistake, as the unconformity is placed between the Hutchinson's-quarry bed and volcanic tuffs which *underlie* the Ototara limestone, while the argument is founded on the assumption that the tuffs *overlie* the Ototara limestone. When I examined Ototara Cape in 1873 I did not notice any unconformity; but I have had no opportunity of examining the locality since Mr. McKay's Report was published. Cape Oamaru is formed by an old volcano, which has broken through the Ototara limestone and was active when the marine beds of Hutchinson's quarry were being deposited. Also the outlier of the Awamoa series on the "Cretaceo-Tertiary greensands and coal-grits," in the Waireka Valley, proves an unconformity between the Awamoa series and the Hutchinson's-quarry beds (which are missing), and

Fig. 2.—*Map of the Valley of the Waitaki and neighbouring region.*



1. Waihao Limestone.
2. Otakaika Limestone.
3. Maerewhenua Limestone.
4. Ototara Limestone.

not between these latter and the Cretaceo-Tertiary, as supposed by Dr. Hector *.

I fail therefore to see any unconformity between the Upper Eocene and the Cretaceo-Tertiary near Oamaru. In his Progress Report for 1881 (Geol. Reports, 1881, p. xxiii), Dr. Hector says, "In the Waitaki Valley, and in the same district as far south as the mouth of the Kakanui River, Tertiary rocks, comprising limestones and calcareous greensands belonging to the Upper Eocene period, are present, resting indifferently on various members of the Cretaceo-Tertiary series;" and in the 'Sixteenth Annual Report of the Colonial Museum,' published in 1882, Dr. Hector says that "in the Waitaki Valley he [Mr. McKay] completely cleared up the evidence on which the subdivision of the Lower Tertiary and Upper Cretaceous strata had been proposed, and obtained a large addition to the collection of fossils" (p. 7) †. I have carefully examined Mr. McKay's 'Report on the Geology of the Waitaki Valley' (*l. c.* p. 56), for proofs of this statement, but without much success, almost all the cases given referring to unconformity of the Pareora system, and not to the Hutchinson's-quarry beds. The rocks are said to be as under (see Map, fig. 2):—

Upper Eocene.

1. Hutchinson's-Quarry Beds: Greensands full of *Waldheimia triangularis* (Hutton).
2. Otakaika Limestone: a calcareous greensand=Nummulitic Limestone.
3. Kekenodon Beds: marly greensands restricted to Wharekauri.

Cretaceo-Tertiary.

4. Grey marls: grey sands.
5. { Maerewhenua Limestone: a calcareous greensand / Waihao Limestone: a white limestone. } =Ototara Limestone.
6. Marly Greensands.
7. Island Sandstone: loose sandy beds with bands of calcareous rock.
8. Coal-beds.

There is no stratigraphical continuity between these rocks and those at Oamaru; and in no locality is the Otakaika limestone seen to overlie the Maerewhenua limestone. Mr. McKay certainly says that "on stratigraphical grounds the Maerewhenua limestone must be regarded as distinct from the Otakaika limestone" (Geol. Reports, 1881, p. 66), and that he will give the evidence further on in his Report; but I have not been able to find it. It would seem therefore that the correlations must depend upon palæontological evidence; but no lists of fossils are given. Mr. McKay's line of proof seems to be different. He says, "In either locality [Oamaru and Maerewhenua]

* In his last Report Mr. McKay has omitted this outlier. He now says that "all the strata developed west of the Waireka Valley and lower part of the Kakanui River pass under the higher part of the Cretaceo-Tertiary series represented by the Ototara calcareous sandstone, all Eocene and Miocene strata lying to the eastward of the great limestone scarp" (Geol. Rep. 1883–4, p. 62). But he gives no reasons for this change, and it is against the palæontological evidence.

† See also Trans. N. Z. Institute, vol. xiv. p. 524.

the limestones are conformable to the beds which underlie, *and these, proving to be the equivalents of each other,* prove also the synchronism of the Ototara and Maerewhenua limestones" (*l. c.* p. 69). But he has just before said (on the same page) that, as the identity of the Ototara stone with the Maerewhenua limestone cannot be proved by fossils, because these are too few in the Ototara stone, "it thus became necessary to prove the relationship of the beds underlying the limestones in the two localities. Here again the tufas of the Waireka Valley differed considerably from the grey sands and marly greensands underlying the Maerewhenua limestone; and while in the latter locality the beds proved highly fossiliferous, fossils were wholly absent in the beds underlying the Ototara stone, *so that in this case also identity could not be proved by means of the fossil contents of the beds.*" I do not wish to dispute this point, as I believe all to belong to the same series. I merely wish to show that he has not proved his case. Indeed, in a further Report, printed in the same volume, Mr. McKay says that "the middle part of the Maerewhenua limestone belongs, I consider, to this horizon [Otakaika limestone], leaving only the lower portion of that rock as the equivalent of the Ototara limestone" (*l. c.* p. 103), thus abandoning his supposed proof altogether. This alteration was made because remains of *Kekenodon* (a Zeuglodont) were discovered in the limestone; and this change alone must throw considerable doubt on the asserted unconformity between the Upper Eocene and Cretaceo-Tertiary rocks in this district.

But, as a matter of fact, I can only find in the Report one place in which an unconformity is said by Mr. McKay to occur between the Upper Eocene and Cretaceo-Tertiary series. In his "Section showing position of coal-seam, Wharekauri" (*l. c.* p. 64), the Otakaika limestone (No. 2) is shown unconformable to the marly greensands (No. 6). The section is described as a sketch of the rocks seen in following up the Wharekauri Creek from the Waitaki; but at p. 73 he says that this section is, he believes, "exactly as the section would appear, provided the obscuring gravels could be cleared away," so that evidently its accuracy may be doubted. Also no evidence is given that these "marly greensands" are not the Kekenodon beds, which are found in the close neighbourhood, it being merely stated that the unconformity is demonstrated "by the absence of the higher part of the marly greensands and the Maerewhenua limestone" (*l. c.* p. 68). Mr. McKay remarks that here "the section of the younger beds is somewhat complicated; and from the fact that the Kekenodon beds are themselves a marly greensand, and their unconformity to the Cretaceo-Tertiary marly greensands not being well marked, the two sets of beds may in places be taken to represent the higher and lower parts of the same series" (*l. c.* p. 73). Evidently there is here no "clear proof" of unconformity, especially as in his Second Report Mr. McKay describes the underlying marly greensands in this locality as "nearly horizontal" (*l. c.* p. 101), and therefore conformable in position to the overlying limestone. He certainly says that "the fossils belonging to the two horizons [of

marly greensands] are very dissimilar" (*l. c.* p. 73); but this statement cannot be received as full evidence until lists of the fossils are published. In fact there appears to be no actual proof of unconformity anywhere; it is merely argued that such an unconformity must exist because the Maerewhenua limestone ought in certain places to come in between the two beds of marly greensand. But this argument rests entirely on the assumption that the Maerewhenua limestone is older than the Kekenodon beds, and differs from the Otakaika limestone, of which no proof at all is given; and, as bones of *Kekenodon* have been since found in the Maerewhenua limestone, it is evident that the whole argument collapses. Indeed, in his Second Report, Mr. M'Kay calls the Otakaika limestone the equivalent of the middle part of the Maerewhenua limestone (*l. c.* p. 104); and if this be so, the Kekenodon beds would appear to be the same as the so-called Cretaceo-Tertiary marly greensands; and the whole of the rocks, from the Hutchinson's-quarry beds down to the marly greensands, would form a single series, No. 1 in the Table (p. 1) being the same as No. 4, No. 2 the same as No. 5, and No. 3 the same as No. 6. It seems to me that this is the only way in which "the evidence on which the subdivision of the Lower Tertiary and Upper Cretaceous strata has been proposed" can be "completely cleared up."

The stratigraphical evidence fails, therefore, equally with the palæontological evidence, to indicate any important break between these rocks, and the whole of them must be included in one system, the *Oamaru System* of Dr. von Haast and myself*.

Discussion.

Dr. Blanford pointed out that of the 48 species from the Curiosity-Shop beds, 10, or more than 20 per cent., are still living. Such a percentage could scarcely be expected in beds older than Oligocene, and was remarkable even in strata of that age.

Dr. Duncan said that he had not found so large a proportion of living species of Echinodermata and Corals even in the Miocene beds of Western India. The more carefully the morphology of late Tertiary forms was studied the fewer were the species which descended from the Tertiaries to the recent faunas. Even in the deep-sea faunas the species which were assigned to old genera belonged to special divisions of them.

Mr. Topley inquired how far Cretaceous forms prevailed.

Mr. Blanford read over the list of genera, which showed that very few, if any, characteristically Cretaceous types occurred in the deposit.

* Some of the "Cretaceo-Tertiary" greensands and coal may, I think, prove to belong to the Pareora system.

42. *On the* Fossil Flora *of* Sagor, *in* Carniola. By Constantin Baron von Ettingshausen, Professor at the University of Graz, Austria. (Read June 24, 1885.)

Having recently brought the third and last part of my work on the Fossil Flora of Sagor before the Imperial Academy of Sciences in Vienna, I take the liberty of reporting to the Geological Society on the facts which may be considered interesting to the science of Palæontology, and on the principal results which have been obtained from my investigations upon the subject. The fossil plant-remains which were brought to light, mostly by my method of impregnating the stones with water and splitting them by freezing, came from fourteen localities:—

1. Beds called "Friedhofschichten," beneath the Brown Coal of Sagor. They occur near the churchyard of Sagor, and consist of yellowish-grey indurated clay. They contain many well-preserved plant-remains belonging to 40 species, many of which have also been found at Häring and Sotzka, and in the Lower Tertiary beds of Switzerland. Among the specimens I have examined there are cones of *Actinostrobus*, seeds of *Embothrium leptospermum* and *Hakea macroptera*, flowers of *Celastrus protogæus*, fruits of *Terminalia Fenzliana*, and leaves of *Corylus MacQuarrii*, *Quercus cuspidata*, *Ficus primæva*, *Cinnamomum lanceolatum*, *Grevillea hæringiana*, *Dodonæa salicites*, *Zizyphus undulatus*, *Eucalyptus hæringiana*, *Dalbergia primæva*, *Cæsalpina Haidingeri*, &c.

2. Beds called "Bachschichten," near Sagor. These and all the following beds here enumerated lie above the Brown Coal. Their plant-remains indicate a flora which in no respect differs from the fossil flora of the Wetterau, of the Brown-coal formation of the Lower Rhine, and of the Aquitanian Tertiary beds of Switzerland. The "Bachschichten," consisting of dark grey indurated clay, are rich in fossil plants, and a careful investigation of them brought to light a flora of 79 species. Of these are particularly to be named *Chondrites laurencioides*, *Davallia Haidingeri*, *Callitris Brongniarti*, *Sequoia Couttsiæ*, *Ostrya atlantidis*, *Quercus Lonchitis*, *Ficus lanceolata*, *Deschmanni*, and *Langeri*, *Laurus tristaniæfolia*, *Sapotacites minor*, *Cissus Heerii*, *Zizyphus paradisiacus*, *Rhus hydrophila*, *Terminalia miocenica*, *Eugenia Apollinis*, *Psoralea palæogæa*, *Palæolobium heterophyllum*, and *Mimosites hæringianus*.

3. Beds called "Tagbau Schichte I." They occur near the smelting-house of the tin-works in Sagor, and consist of yellowish-grey or yellowish-white indurated clay, which is not so rich in fossils as the preceding beds. Of the species to be found there, I may mention *Taxodium distichum miocenicum*, *Sequoia Tournalii*, *Pinus hepios*, *Myrica deperdita*, *Fagus Feroniæ*, *Pterospermum sagorianum*, *Bursaria radobojana*, *Dalbergia valdensis*.

4. Beds called after the "Francisci Erbstollen," near the Sagor

works. They show a bluish-grey shale, which seldom contains fossils. As yet only the following species have been discovered:—*Glyptostrobus europæus*, *Sequoia Couttsiæ*, *Ficus sagoriana*, *F. bumeliæfolia*, *Banksia longifolia*, *Andromeda protogæa*, and *Eucalyptus oceanica*, all very common in the beds Nos. 2, 8, 9, 11, and 14.

5. Beds near Sagor, containing fossil fishes, but very few fossil plants. They occur in a grey indurated clay, and the latter includes *Glyptostrobus europæus*, *Sequoia Couttsiæ*, *Ficus bumeliæfolia*, *Cinnamomum polymorphum*, *Bumelia oreadum*, and *Andromeda protogæa*.

6. Beds called "Tagbau Schichte II.," near Sagor. The fossil plants are here to be found in a light or yellowish-grey indurated clay, and belong to *Chara Ungeri*, *Ch. Langeri*, *Glyptostrobus europæus*, *Sequoia Couttsiæ*, *Zostera Ungeri*, *Castanea atavia*, *Quercus Lonchitis*, *Ficus bumeliæfolia*, *Pisonia eocenica*, *Banksia longifolia*, *Apocynophyllum breve-petiolatum*, *Andromeda protogæa*, *Robinia crenata*, *Dalbergia hæringiana*, *Cassia palæogæa*, and *Podogonium Lyellianum*.

7. Close by the village of Godredesch, near Sagor, there are some beds consisting of dark-grey indurated clay, like that of the beds No. 2. They contain plant-remains which have been referred to 11 species. With the exception of *Myrsine Endymionis*, *Cussonia ambigua*, and *Pistacia palæo-lentiscus*, these also occur in the beds No. 2.

8 and 9. Near the village of Savine, in the neighbourhood of Sagor, there are two very rich localities of fossil plants. The beds consist of a light- or yellow-grey marl, which contains well-preserved fossils. From this I have obtained a flora consisting of 313 species, which form the principal part of the fossil flora of Sagor. The locality No. 8 is the quarry from which the most valuable fossils came. Of these I mention the following as possessing special interest:—*Muscites savinensis*, *Blechnum Braunii*, two forms of *Equisetum*, *Cunninghamia miocenica*, *Smilax paucinervis*, *Pandanus carniolicus*, *Laurelia rediviva*, *Laurus stenophylla*, *Litsæa dermatophyllum*, *Conospermum macrophyllum*, *Cenarrhenes Haueri*, *Persoonia cuspidata*, two forms of *Hakea*, *Embothrium stenospermum*, *Lomatia oceanica*, *Olea carniolica*, *Fraxinus primigenia*, *Sapotacites chamædrys*, *Diospyros bilinica*, *Symplocos savinensis*, *Callicoma microphylla*, *Clematis sagoriana*, *Tetrapteris minuta*, six species of *Celastrus*, *Pomaderris acuminata*, *Ptelea intermedia*, *Ailanthus Orionis*, *Vochysia europæa*, and nine species of Papilionaceæ.

The locality No. 9 is the top of a coal-pit from which the fossil plants came. I have selected for mention a few of the many new forms which I found there:—*Actinostrobus miocenicus*, *Leptomeria distans*, *Embothrium macropterum*, *Notelæa rectinervis*, *Fraxinus savinensis*, *Alstonia carniolica*, *Chrysophyllum sagorianum*, *Vaccinium palæo-myrtillus*, *Loranthus palæo-exocarpi*, *Bombax sagorianum*, *Pittosporum palæo-tetraspermum*, and *Ptelea microcarpa*.

10. Islaak, near Sagor. The fossil plants occur here in greyish white marl, looking somewhat like that of Savine. All the fossils

which I discovered in it are to be found also at Savine, excepting *Heliotropites parvifolius.*

11. Trifail. The beds resting upon the coal strata are rich in different plant-remains, which mostly occur in a dark grey indurated clay, like that of the locality No. 2. The most interesting of the species collected here are the following:—*Cystoseira communis, Taxodium distichum miocenicum, Pinus palæo-tæda, Fagus Feroniæ, Castanea atavia, Banksia Haidingeri, Bumelia scabra, Diospyros hæringiana, Sapindophyllum paradoxum, Carya trifailensis, Prunus mohikana*, and *P. palæo-cerasus.*

12. Hrastnigg. I obtained from a coal-pit the following species of fossil plants, which occur in a light-grey marl:—*Hypnum sagorianum, Glyptostrobus europæus, Sequoia Couttsiæ, Typha latissima, Cinnamomum polymorphum, Banksia longifolia, Bumelia Oreadum, Andromeda protogæa, Anœctomeria Brongniartii, Nymphæa gypsorum, Eucalyptus oceanica*, and *Phaseolites microphyllus.* Of these, nine occur also at Savine.

13. Bresno. In a yellowish-grey marl here I found well-preserved fossil plants belonging to the following species:—*Glyptostrobus europæus, Sequoia Tournalii* and *Couttsiæ, Carpinus Heerii, Ficus tynx* and *bumeliæfolia, Cinnamomum polymorphum, Banksia longifolia, Sapotacites sideroxyloides* and *emarginatus, Mimusops tertiaria, Bumelia Oreadum, Andromeda protogæa, Celastrus protogæus*, and *Eucalyptus oceanica.*

14. Tüffer. The fossil plants occur in a light or somewhat reddish-grey marl-slate resembling that of Savine. I found there many well-preserved fossils belonging to *Hypnum sagorianum, Glyptostrobus europæus, Sequoia Couttsiæ, Pinus palæo-tæda, Typha latissima, Myrica salicina, Castanopsis sagoriana, Quercus Lonchitis, Ficus sagoriana* and *bumeliæfolia, Pisonia eocenica, Hedycarya europæa, Laurus Haueri, Cinnamomum polymorphum, Banksia longifolia, Sapotacites sideroxyloides, Bumelia Oreadum, Andromeda protogæa, Celastrus protogæus, Eucalyptus oceanica, Eugenia Apollinis.*

I proceed now to explain the general results of my investigations of the Sagor fossil flora:—

1stly, the fossil flora of Sagor contains at least 170 genera and 387 species, which are distributed under 75 families. Of the species, 21 belong to the Cryptogamæ, 18 to the Gymnospermæ, 14 to the Monocotyledons, 117 to the Apetalæ, 61 to the Gamopetalæ, and 156 to the Dialypetalæ. 18 species were aquatic, but all the others terrestrial plants.

2ndly, the fossil flora of Sagor consists of two floras of different ages, but immediately following one another. The beds No. 1, which underlie the coal, and may be the basement beds of the Tertiary of Sagor, include a flora which existed in the last section of the Eocene period. The other beds, resting upon the coal, contain the remains of a flora belonging to the first section of the Miocene period.

3rdly. In consequence of the great diversity of fossil plants, and

their abundance in some of the localities, the elements of the floras are so distinctly marked as to place it beyond doubt that the Tertiary flora is to be considered the origin of all the living floras of the globe, a conclusion to which the investigations of the floras of other Tertiary localities have already led. In the fossil flora of Sagor the following floras are represented :—

AUSTRALIA by *Actinostrobus*, *Casuarina*, *Leptomeria*, *Santalum*, sp., *Conospermum*, *Persoonia*, *Grevillea*, *Hakea*, *Lambertia*, *Lomatia*, sp., *Banksia*, *Dryandra*, *Notelæa*, *Myoporum*, *Loranthus*, sp., *Callicoma*, *Ceratopetalum*, *Sterculia*, sp., *Dodonæa*, sp., *Bursaria*, *Elæodendron*, sp., *Pomaderris*, *Eucalyptus*, *Kennedya*.

NORTH AMERICA and MEXICO by *Taxodium*, *Pinus*, sp., *Myrica*, sp., *Betula*, sp., *Fagus*, sp., *Ostrya*, sp., *Quercus*, sp., *Ulmus*, sp., *Platanus*, sp., *Symplocos*, sp., *Vaccinium*, sp., *Cornus*, sp., *Magnolia*, sp., *Acer*, sp., *Evonymus*, sp., *Prinos*, *Berchemia*, *Ilex*, *Carya*, *Ptelea*, sp., *Prunus*, sp., *Robinia*, and *Erythrina*.

CALIFORNIA by *Libocedrus*, sp., *Sequoia*, *Pinus*, sp.

BRAZIL and TROPICAL SOUTH AMERICA IN GENERAL by *Blechnum*, sp., *Ficus*, sp., *Pisonia*, sp., *Persea*, sp., *Ocotea*, *Andromeda*, sp., *Weinmannia*, sp., *Bombax*, sp., *Ternstrœmia*, *Tetrapteris*, *Banisteria*, *Sapindus*, sp., *Xanthoxylum*, sp., *Vochysia*, *Dioclea*, *Machærium*, *Cassia*, sp., *Acacia*, sp.

CHILI by *Podocarpus*, sp., *Laurelia*, *Cassia*, sp.

INDIA and EAST-INDIAN ISLANDS by *Castanopsis*, *Ficus*, sp., *Phœbe*, sp., *Cinnamomum*, *Mimusops*, *Sterculia*, *Pterospermum*, *Pittosporum*, sp., *Dalbergia*, *Sophora*, sp., *Cæsalpinia*.

CHINA and JAPAN by *Glyptostrobus*, *Cinnamomum*, sp., *Hydrangea*, sp., *Acer*, sp., *Styphnolobium*.

EUROPE by *Pinus*, sp., *Phragmites*, *Zostera*, *Typha*, *Alnus*, *Carpinus*, *Corylus*, *Castanea*, *Ulmus*, sp., *Ligustrum*, *Olea*, sp., *Fraxinus*, sp., *Vaccinium*, sp., *Acer*, sp., *Pistacia*, sp., *Prunus*, sp., *Psoralea*, sp.

The CANARIES by *Davallia*, sp., *Laurus*, sp., *Persea*, sp.

AFRICA by *Callitris*, *Kennedya*, sp., *Olea*, sp., *Coussonia*, *Celastrus*, sp., *Pterocelastrus*, and *Rhus*, sp.

NORFOLK ISLAND by *Araucaria*, sp., and *Elæodendron*, sp.

NEW ZEALAND by *Hedycarya*, sp., *Cenarrhenes*, *Weinmannia*, sp.

43. A SKETCH *of the* GOLDFIELDS *of* LYDENBURG *and* DE KAAP, *in the* TRANSVAAL, SOUTH AFRICA. By W. HENRY PENNING, Esq., F.G.S., &c. (Read May 27, 1885.)

CONTENTS.

§ 1. ESTIMATED EXTENT OF THE GOLD COUNTRY.

THE goldfields of the Tati are about 100 miles beyond the Limpopo River, the northern boundary of the Transvaal, and those of Hartley Hill are 250 miles still further towards the interior. These fields have been described by the late Mr. Thomas Baines, F.R.G.S., in his work on 'The Gold Regions of South-eastern Africa' *, and prove the extension of auriferous veins through at least 7½ degrees of latitude, *i. e.* from the Kaap Valley to Hartley Hill (18° to 25° 30′ S.). From the gold-lodes west of Pretoria to the site of Herr Carl Mauch's discovery near the Olifant's River in 1868, a space intervenes covering three degrees of longitude (28° 30′ to 31° 30′ E.). Gold has been found at many points within, as it must also be found beyond, the area thus arbitrarily limited, which certainly covers not less than 100,000 square miles.

§ 2. LYDENBURG AND DE KAAP GOLDFIELDS.

The Lydenburg and De Kaap Goldfields, as at present known, are included within a line passing W. from the northern point of Swaziland, through the Tafelkop mountains, thence N. through Lydenburg and along the Orighstad River to its junction with the Blyde. Now turning S., the line follows the edge of the berg, or eastern face of the Drakensberg mountains, to near Spitzkop, and thence back to its starting-point on the border-mountains of Swaziland. (See Map, Quart. Journ. Geol. Soc. vol. xl. p. 658; and Map in the Journ. Soc. Arts, vol. xxxii. 1884, p. 609.) This area extends over about 1¼ degree of latitude (24° 35′ S. to 25° 50′ S.), and, on the average, half a degree of longitude (30° 30′ to 30° 45′ on the N., 31° 15′ on the S.), thus being about 3000 square miles. For some notes on this country see a paper by the author in Journ. Soc. Arts, vol. xxxii. 1884, p. 608.

* Stanford, London, 1877.

The physical features of the triangular tract of country occupied by the Lydenburg and De Kaap goldfields, between Swaziland, the Tafelkop, and the junction of the Blyde and Orighstad rivers, may be briefly described. The western side is upon the Drakensberg mountains, the highest part of the range following a nearly N. and S. line, from near the junction of the rivers, by Mauch's Berg and Spitzkop to the Tafelberg, whence the Kaap mountains branch off to the E. towards the Makoujwa mountains, which form the N.W. boundary of Swaziland. Part of the range N. of the Tafelberg, and between it and the Krokodil River, is named the "Godwaan Plateau." The Drakensberg mountains fall gradually away to the W., but present a very precipitous face (or "krantz," as it is called) to the E. This krantz overlooks the lower country, which is traversed by the Sabie and Krokodil Rivers, with their affluents, the united waters of which, with those of the Komati, fall into the Indian Ocean north of Delagoa Bay.

It is a noteworthy feature that the sources of most of these rivers are a long way to the westward of the highest parts of the mountain-range. The general surface slopes W., but the rivers flow E., passing through deep gorges, called "poorts," in the mountains. The Blyde and Orighstad rivers unite at the back of the range, and pass through the "Blyde Poort." The Eland's Spruit joins the Krokodil River, just behind the Godwaan Plateau and before entering the "Krokodil Poort." In a similar manner the Komati and Krokodil Rivers unite (further to the east) just before passing through the "Lower Komati Poort" in the Lebombo Mountains *.

Mauch's Berg is the highest feature of the range, but Spitzkop is the most prominent, being an isolated peak in the midst of a comparatively level plain or terrace which borders the low country. There are very few places, except in the valleys, from which Spitzkop cannot be seen, within a radius of fifty or sixty miles. "In the angle formed by the junction of Eland's Spruit with the Krokodil River is the Godwaan Plateau, an elevated tract some four or five miles in width" †.

1. *The Geology of the Kaap Valley &c.*—The following are the main geological features observed by me while travelling:—

The oldest rocks of the goldfields are those of the Kaap Valley and those bordering the Krokodil River, as far as yet examined, also, doubtless, occupying the almost unknown region "below the berg" in the direction of the Blyde Poort.

2. *Granitic? Rocks.*—An intrusive plutonic rock, geologically newer than the stratified rocks, but still in an inferior position, occupies the whole of the lower ground of the western part of the Kaap Valley. It resembles coarse granite, and consists of quartz and felspar, with but little, if indeed any, mica in its composition. Although this granite (for such it may be called) forms generally

* See "A Sketch of the High-level Coalfields of South Africa," read before the Society on 5th March, 1884 (Q. J. G. S. vol. xl. p. 658). See also Loveday's Map of the Lydenburg Goldfield, Pretoria, 1883.

† 'Guide to the Goldfields of South Africa,' Pretoria, 1883, pp. 44–46.

the lower ground of the head of the valley, it rises into hills and ridges, some of which have a considerable elevation. In some cases it has weathered into bare rounded bosses bearing a striking resemblance to *roches moutonnées*; but over the greater part of the area the surface of the granite is decomposed into a soft brown substance very much like an alluvial loam.

In the Kaap Valley the surface of the granite forms an ellipse about 17 miles in length by 10 miles in width, with a narrower prolongation in a northerly direction. It widens out again towards the Krokodil River, beyond which it passes in under a series of rocks which rest unconformably upon those with which it has thus far been in contact, and which will probably be found to occupy the remainder of the Kaap Valley.

This mass of granite represents a great centre of plutonic upheaval, of course posterior to the period of the Kaap-valley rocks, which it has greatly tilted all around its margin; it was, however, anterior to the deposition of the rocks of the overlying unconformable formation, as they are still nearly horizontal.

3. *Silurian? Rocks.*—Nearly all around the granite centre is a series of rocks which have been tilted by it into a more or less vertical position. These rocks are siliceous and argillaceous, rarely, and then but slightly, calcareous, being mainly schists, shales, cherts, and quartzites. I believe them to be "Silurian" rocks; but, with the exception of an unreliable report of Graptolites having been observed, there has been hitherto (so far as I am aware) a total absence of fossil evidence.

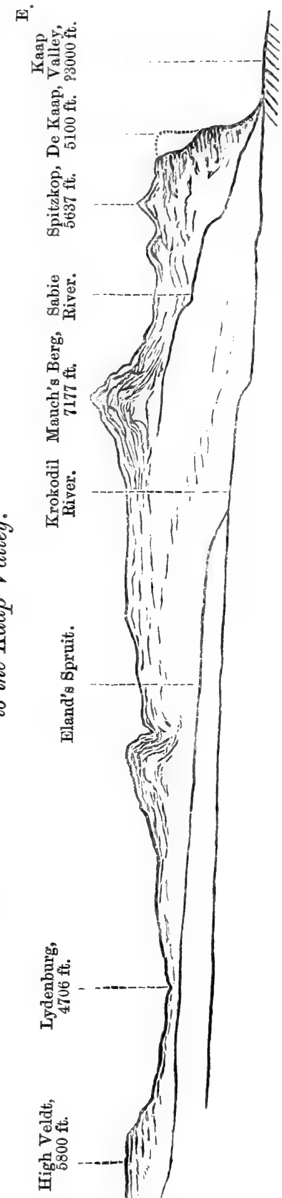


Fig. 1.—*Diagram-Section showing the General Form of the Country and the Fall of the Rivers from the "High Veldt" to the Kaap Valley.*

Both the granite and the stratified rocks of this region are traversed by intrusive dykes of trap-rock, mostly diorite, some narrow, others of great width, and frequently traceable at the surface for many miles. The main dykes generally, but not always, follow a nearly N. and S. line; the branches run in various directions.

4. *Sections and "Reefs," a–f.—a.* At the southern extremity of the granite* some gold-mining has been carried on upon what is known as "Moodie's Reef." This "reef" is situated just N. of "Crawford Creek" (so called on Loveday's map) which flows here nearly E., then turns northward to join the Kaap River. This creek is really a very deep gorge; on the south side the mountain rises to perhaps 1500 feet in height; on the north a long spur branches out from the mountain, also following an easterly direction, its ridge gradually descending, but being at this point about 800 feet high. It coincides with the strike of the beds, which are vertical, as the creek coincides with this also until it rounds the end of the spur and turns towards the flat to the north. A difference in the composition of the beds has, doubtless, been the chief cause of the formation of this steep and peculiar gorge, roughly parallel to the boundary of the granite flat, from which it is separated only by the narrow but lofty ridge along which some of the mines are situated.

The rocks of the ridge are schists, shales, cherts, and sandstones, which strike a little S. of E., and have a dip of about 90°, that is, they are nearly vertical. A bed, or "seam," of white crystalline quartz occurs about the centre of the ridge, coinciding with it and with the ordinary stratified rocks in strike and dip.

The rocks of the mountain are principally cherts, with some highly altered shales, the same in strike and dip as those of the ridge. In the gorge are loose pieces of chlorite-schist, but that rock was not seen here in place.

A few miles to the south on the high lands, in a farm † cursorily inspected, the rocks seen along the lines traversed were, in ascending order from the edge of the mountain, cherts, shales, and sandstones, schists and conglomerates. The beds strike E.S.E. and are nearly vertical, but not quite so much so as nearer the granite; they dip about 85° to the S.

"Moodie's Reef" (so called) consists of a deposit of white crystalline quartz, of the kind known by miners as "sugary quartz," varying from 1 foot to 2 feet wide, and *interstratified with the rocks of the district.* It might possibly happen for it to occupy such position even if it were a true vein or lode; but I must consider it as a *bed* of auriferous quartz. It is just as much so as the schists and cherts are beds, because in so many instances, and over so large an area, gold-bearing deposits of quartz, whatever may be the strike and dip of the beds, occupy a similar position. This is not by any means the usual mode of occurrence of gold, which is mostly found in veins,

* In Farm no. 492 on Loveday's map.

† No. 505 on Loveday's map.

although "it is also more rarely met with in the form of grains in the shales and other unaltered stratified rocks" *: and "bands of different kinds of iron-ores are said to occur in some of the clay-ironstone interstratified with the slates, and associated with these are certain conformable beds, from which the greatest riches of gold have been obtained" †.

Mr. J. A. Phillips (quoting Mr. R. B. Smyth) says:—"Gold is now found to occur not only in the quartz-veins and in the alluvial deposits derived from them and the surrounding rocks, but also in the clay-stone itself; and, contrary to expectation, flat bands of auriferous quartz have been discovered in dykes of diorite, which intersect the Upper Silurian or Lower Devonian rocks. Quartz of extraordinary richness has been obtained from these bands" ‡. In the former case, bands are said to occur, but would appear to be exceptional; in the latter the flat bands are in dykes of diorite, therefore veins, and not beds at all. The auriferous beds now described are numerous and rich, in both the Silurian (?) and Devonian (?) formations, and possess an additional interest from their (so far as I am aware) *novel* mode of occurrence.

One side of the quartz seam called "Moodie's Reef," which would be its north wall if a true vein, but is what was originally its underside as a bed, is plentifully sprinkled with specks of gold, rather fine, but still quite visible to the naked eye. There is gold also in the body of the quartz; but, so far as I have been able to ascertain, only in small quantity. The abundance of the metal on one side must, however, give a good average yield of gold per ton. On the same side of the quartz there is also a streak of green mineral, not carbonate of copper, which at first sight it resembles, but probably chlorite or some form of serpentine, traces of which are also apparent in the body of the quartz.

There are other seams of auriferous quartz in the immediate vicinity; some of these, discovered before the time of my visit, did not come under my notice—others have been opened since, and some of them, the "Ivy Reef" for example, are said to be very rich indeed in gold.

b. Some miles east of Moodie's Reef the "Umvoti Reef" occurs as a seam of dark-grey quartz, sometimes almost black and flint-like in appearance. This seam is also in the bedding of the rocks, which are hard dark-coloured schists, quite vertical, but here striking to N.E.

The "Umvoti Reef" is also a seam (in the bedding) of dark-grey quartz, varying from 6 to 12 inches in thickness, and contains fine gold; the sample assayed by myself, and in which no gold was visible, yielded the metal at the rate of 16 oz. 13 dwt. 8 grs. to the ton §.

c. "Barber's Reef" is close by the Umvoti, but appears to be a true lode, as it is transverse to the strike of the stratified deposits.

* Jukes's 'Manual of Geology,' 3rd edit. 1872, p. 303.

† *Ibid.* p. 305.

‡ 'Elements of Metallurgy,' 1874, p. 693.

§ Described in the author's Report, November 1884, as yielding gold in the proportion of from 1 to 140 oz. per ton of 2000 lbs.

It is of a different character—a creamy-white compact quartz-reef, from 4 to 6 feet wide, dipping E. 70° and striking E. of N., whilst the stratified rocks here strike N.E., a difference of upwards of 30 degrees.

d. Still skirting the granite, but now in a northerly direction, we come to the "Caledonia Reef," on the southern or right-hand bank of the Kaap River. The rocks here are schists, shales, cherts, and quartzites, nearly vertical and striking N.N.W. by N. In one place, upon an isolated hill some 700 or 800 feet above the river, the reef was exposed. It is a seam of quartz, which may or may not be exactly in the bedding, in close contiguity to a large dyke of trap-rock.

The "Caledonia Reef" apparently strikes with the strata, and is a vein of grey quartz, slightly honeycombed, the cavities generally filled with limonite and sometimes enclosing crystals of carbonate of copper and other minerals. The vein passes down vertically, varies from 12 to 18 inches in width, and is auriferous throughout.

Although this reef strikes almost, or quite, in the same direction as the schists, I am inclined to regard it as a true vein rather than as a seam or bed, because there are smaller veins, or "leaders," branching from it with a different direction; also because there is, on the west side, another reef of quartz, greatly resembling that of Moodie's Reef and following a somewhat transverse direction. As both cannot coincide with the local strike, one, at least, must be a true vein; of the two, I think, for the reasons given, that one is the Caledonian reef. The other reef "gave a prospect of coarse gold upon being simply crushed and washed" on the ground.

e. Some 7 or 8 miles due north from the Caledonia Reef, the rocks on two other gold-bearing properties were found to "consist of siliceous beds so highly altered and contorted as to have been, in part, converted into jasper. Further east, and probably higher in the series, shales come in, then another series of hard grey schists; the same strike, W.N.W., and the same vertical position being still maintained. These old stratified rocks are traversed by dykes of diorite and other plutonic rocks in various directions"*.

Just west of Kaffir Spruit a seam has been opened of "grey quartz, much stained by oxide of iron. This vein can be followed for a considerable distance, striking W.N.W.—it is almost vertical, but hades slightly to the eastward. It is 18 or 20 inches wide, and carries gold, as tested, in the proportion of 2 oz. 1 dwt. 1 gr. to the ton of 2240 lbs. Two other trials of the same stone gave a mean yield of 1 oz. 15 dwt. 14 grs. to the ton.

"To the west of the above lode are some leaders of black quartz, which gave 'good prospects' of gold. On the east side of Kaffir Spruit is a vein of grey quartz, 18–24 inches wide, apparently a continuation of the above lode, being just in the line, and having the same width and direction †". This is evidently an interstratified seam, being coincident with the shales in dip and direction of strike.

* The author's Report, Nov. 1884.

† Report, Nov. 1884.

f. Several miles to the N.W., and still bordering the granite, we come to the so-called "Welcome Reef," on the south bank of the Lampongwana river, and 10 or 12 miles due east of De Kaap. Here the rocks are similar to those of the Caledonia reef, a soft talcose or steatitic foliated schist being also exposed—still vertical, but now striking N.W. The reef is a seam of quartz, apparently striking with the stratified rocks.

The "Welcome Reef" appears to follow the strike of the rocks, N.W., but this is not certain, and it dips somewhat into the hill on the west, whilst the strata, being here tilted by the granite, might be expected to dip, if at all, the other way; the evidence, however, is very obscure. The lode varies from 6 inches to 6 feet, and consists of white and tinted glassy quartz, containing much earthy carbonate of copper and oxide of iron, with occasional specks of visible gold. Some veinstone, taken at a depth of 15 feet, yielded gold at the rate of 1 oz. 4 dwt. 21 grs. per ton. All stone having been rejected in which the metal could be seen, it will be within reasonable bounds to assume an average of between $1\frac{1}{4}$ and $1\frac{1}{2}$ oz. per ton.

The above observations extend about two thirds around the central boss of granite, and show that thus far the strike of the stratified rocks coincides with its margin, varying, as it does, from S. of E., through N.E. and N.N.W. to W.N.W. This affords ample evidence that their upheaval into a vertical position is due to the intrusion of the granite. Along the western side of the granite the same phenomenon is evident, although not so clear, owing to slips and accumulations of talus under the high krantz; but the edges of vertical rocks may be occasionally seen, striking in a generally northerly direction. I think there can be but little doubt, if any, that the Kaap Mountains and the Godwaan Plateau nearly coincide with the margin of the granite.

The north-westerly strike, which was the last observed, appears to be continued, but rather more westerly, beneath the Godwaan Plateau, as vertical schistose rocks, with W.N.W. strike, are seen in the bottom of the Eland's Spruit valley. Between those points there is a ridge or spur jutting out from the "berg" a little N. of De Kaap, in an E.N.E. direction. The beds forming this ridge are quartzose foliated schists, of a peculiar character and different from anything I have seen elsewhere. The strike of the beds coincides with the ridge, W.S.W., and they dip very sharply to the N., indeed are almost vertical. To the north of the ridge the granite again comes to the surface, and, as stated before, widens out towards the Krokodil River, and then passes in under a series of rocks newer than those above briefly described. It probably forms the low country "below the berg," or rather perhaps the flank of the mountains to the north, and sweeps round by the Olifant's River,—at any rate granite has been observed far away to the northward. "Beyond the Limpopo both Jeppe's and Baines's maps indicate 'Granite' up the Bubye River, and the latter portrays a 'high

granitic range' running in a N.E. direction from lat. 20° 30′ to 17° 30′ S.* "

5. *Devonian? Rocks.*—After the rocks which I have referred to as Silurian had been tilted into their present vertical position by the upheaval of the central mass of granite of the Kaap Valley, they were cut down to a "plain of (probably) marine denudation." This old plain is at an elevation of 1700 or 1800 feet above the present general level of the Kaap Valley, which has, of course, been much more recently excavated. Upon the upturned and denuded edges of the Silurian rocks, those which I here provisionally term "Devonian" were deposited. (The "Megaliesberg Beds" of my paper on the Coalfield, Q. J. G. S. vol. xl. p. 660.)

At the base of these Devonian rocks is frequently seen a series of conglomerates and sandstones (with some shales), which is fairly well exposed about De Kaap, "formed from the waste of the underlying Silurian beds, and of any quartz veins that they may have enclosed" †. The Kaap sandstones are highly crystalline, some coarse, others fine in texture, in thick beds which have weathered into massive tabular blocks, which impress a peculiar distinctive character upon the appearance of the country.

These sandstones and conglomerates thin out to the north, as the immense series of shales (with occasional sandstones), by which they are overlain, rests directly upon the granite on the other side of the Krokodil River. At De Kaap they afford additional evidence that rich gold-lodes exist below them, or at no great distance, in the Silurian rocks from which they were derived; for they are frequently auriferous, containing not only fine gold but nuggets, especially the conglomerates. An analogous case, but of course one of recent date, is the occurrence of fine gold in the sand of the sea-shore (and probably, of course, gold in the gravels) upon the west coast of New Zealand.

Above the sandstones comes a very large series of shales and flagstones, fissile and thin-bedded, which generally are grey, but weather to yellow or dirty yellow or dirty brown. In some localities, as along the valley of the Eland's Spruit, there occurs a series of cherts and quartzites, which appear to replace the lower shales.

High up in the shales, but not by any means near the top of them, are two or more series of a peculiar, blue, fine-grained, calcareosiliceous rock, to which Mr. A. C. Cruttwell and myself have given the name of "chalcedolite." We adopted this term in consequence of the chalcedonic texture frequently displayed—indeed, some portions of the rock are true chalcedony. Sometimes it occurs in amorphous masses, weathered to a grey colour, and to a peculiar, rough, trachyte-like surface; but mostly in thin beds, 2 or 3 inches in thickness, with earthy partings, the lines of lamination being wavy and indistinct, except where exposed by weathering. The rock appears to be the result of intermittent deposition, probably

* Guide to the Goldfields, p. 62.
† Report, Dec. 1884.

in an inland sea, from water holding much silica and some lime in solution.

The chief exposure of these chalcedolites is along the Blyde-river valley, best seen on its western side or escarpment, where the rock occurs in two series, the lower several hundred feet in thickness, with shales above, below, and between. It contains fine gold in places, and, where in a decomposed state, it has been worked as so-called "rotten-reef" to a considerable extent. There are numerous old workings in it, following fissure-veins or old weathered crevices, frequently on an extensive scale, as in Rotunda Creek, which opens to the Blyde River, and again a few miles to the west of Pretoria.

Still higher up in the shales, there are series of sandstones, some compact and very highly metamorphosed, others more coarsely crystalline, and resembling those of De Kaap. These and the associatad conglomerates are sometimes found to be auriferous.

These Devonian rocks moreover are traversed by dykes of diorite and other trap rocks; and immediately upon them, with an unconformity not very strongly marked, but still probably representing an extended period, rest the "High-Veldt Beds" *.

6. *Sections and Auriferous Deposits*, *a′–q′*.—The following are brief notes of sections, commencing on the south at De Kaap, and ending on the north in the Orighstad Valley:—

a′. At De Kaap "the lowest rocks of this series are highly crystalline sandstones and conglomerates....Immediately above the sandstones is a series of shales;" these are overlain by another series of sandstones on the higher ground to the west, succeeded by more shales which pass in under, or are replaced by, the cherts and quartzites of the Eland's-Spruit Valley.

The conglomerates here, and in a less degree the sandstones, are auriferous (see above, p. 576). The shales above the sandstones enclose veins of auriferous quartz, one of which yielded gold at the rate of upwards of an ounce to the ton†.

b′.—The Godwaan Plateau is on the upper of the two series of sandstones, which are exposed to a considerable depth in many natural sections, such as krantzes and caves, as well as in the mines. Shales occupy the surface, sloping down towards Eland's-Spruit Valley; both these and the sandstones are crossed by quartz reefs and dykes of diorite.

There are several "reefs" on this plateau, some of them being very rich in gold. (1) The "Homeward-Bound Reef," which, so far as opened, is a vein of soft saccharoid quartz, with some hard quartz, much earthy matter, and oxide of iron, several feet in width, striking N. and S., and enclosed in fairly well-defined walls. The lode, however, is much split up, and, as it were, spread out near the surface, becoming more compact and regular below. I have no data for estimating the yield of gold from this lode, which is certainly rich, for some hundreds of ounces are obtained every week by small machinery. The gold is remarkably fine, like flour, and requires,

* Quart. Journ. Geol. Soc. vol. xl. (1884), p. 660.

† Report, Dec. 1884.

therefore, great care in manipulation. There is a casing of grey, honeycombed quartz, several inches thick, on the west side of the lode, which contains silver. I have made no assay of this, but was informed that Messrs. Johnson and Matthey had certified 16 oz. to the ton.

(2) Three or four hundred yards to the east is "Rautenbach's Reef," a mass of soft, earthy, auriferous ground, which appears to occupy nearly the whole of the ridge parallel to that of the 'Homeward Bound Reef." There are in it, however, numerous quartz strings, dipping from either hand towards a central line, and seeming to indicate a downward extension of the lode in a more restricted form. Some spots are very rich in fine gold, others poor and even barren, the metal not being at all equally distributed.

Since my last visit to this place, I have received a letter, dated 13 Dec., 1884, from which the following is a short extract:—"In continuing the large cutting....I have come on a very large lode of rich quartz; it is about 13 feet wide, and runs to all appearance due E.; it seems to branch out from the Homeward Bound Reef. I have taken out of it to-day about 60 tons, and it is very easily worked." There are other auriferous reefs on the plateau, some rich in gold, but only the above are yet opened to any extent.

c'. About 14 miles to the westward of the Godwaan Plateau, I have examined a block of farms on the table-land between Eland's Spruit and the Krokodil River, finding the rocks to be:—"Sandstones on the higher ground....resting upon grey thin-bedded shales, which, in turn, rest upon a series of beds of chert, quartzite, and arenaceous shales" *.

Upon the block of farms between Eland's Spruit and the Krokodil River I traced the outcrop of several quartz-reefs; these have not been opened up, but the surface-specimens yielded gold in promising quantity.

About 10 miles still further west the main road from Natal passes down a very steep hill into the Krokodil Valley, and shales are exposed from top to bottom of the descent, except where intersected by some large diorite dykes.

About thirty miles further down the valley, and on the opposite side of the Krokodil River, the road from Spitzkop also comes down a very steep incline. This shows shales in its upper portion, which, part way down the hill, rest directly upon the granite of the Kaap Valley.

At the head of the Stadt's River, which about here joins the Krokodil, I went over a farm, finding it to consist of shales, except on the highest ground to the N.W., which is sandstone. The whole country from here to Lydenburg is nearly all shale, with sandstone on the higher ridges.

d'. Around Lydenburg the rocks consist principally of a series of shales, several hundred feet in thickness, with occasional beds of sandstone, dipping to the westward. On the Lydenburg townlands "a reef of quartz, 2 feet in width, crops out along the top of

* Report, March 1884.

the ridge on the west side of the Dorps River, striking N.N.E., and having an easterly dip of about 80°. This reef is in a diorite dyke, to the depth already proved of over 50 feet, and will yield gold at the rate of 9 dwt. to the ton*. . . . . The shales and sandstones are highly metamorphosed throughout, but especially so where in contiguity to the numerous dykes of diorite and other plutonic rocks by which they are traversed in various directions. As a rule, such dykes are more or less vertical in relation to the strata through which they pass; but there are several on the town-lands that almost if not quite coincide with the stratification."

Six miles north of the town the Pilgrim's-Rest road winds down a steep hill to the "drift" across the Spackboom River. The road-cutting exposes grey shales all the way down, except where they are broken through and locally displaced by a diorite dyke, which the section shows plainly in the various stages of concentric weathering. The shales below the dyke are black, like slate in appearance and composition, but without any sign of cleavage. (The absence of true slate is somewhat remarkable. I have not yet seen it in any part of South Africa.)

e′. From Lydenburg the country and the beds rise to the eastward with a long "dip-slope," and a few miles in that direction lies the "Paarde-Plaatz," or Horse-farm, belonging to the town. "The rocks of Paarde-Plaatz are altered shales on the western margin, which overlie a series of crystalline false-bedded sandstones that crop out along the edge of the mountain, and form the higher grounds in the centre and on the east side of the farm. These sandstones, in turn, rest upon another series of shales that occupy the lower grounds, and stretch away to the eastward"†. There are numerous seams of quartz, varying from 2 to 18 inches in thickness, interstratified with these sandstones and lower shales, and these will be referred to presently, as they are rich auriferous deposits. There are also vertical veins of quartz which contain gold.

Paarde-Plaatz.—In June last year, when examining this ground, I picked up a loose piece of crystalline quartz, very promising in appearance, and in such a position that it must have come from a reef within a short distance. It yielded gold at the rate of upwards of 5 oz. to the ton. There was no sign of the outcrop of a true lode, so trenches were cut under my direction, and by this means the source of the loose lumps of quartz was discovered. It proved to be a flat seam of red-brown crystalline quartz, perfectly interstratified with the bedded rocks. Numerous other auriferous quartz-seams coincident with the stratification were afterwards opened a few feet apart in the shales and sandstones. These seams extend over a considerable area, and vary in thickness from $1\frac{1}{2}$ to 18 inches, and in yield of gold (some barren) from 9 dwt. 1 gr. to 6 oz. 17 dwt. 10 gr. per ton. The average of fourteen assays of stone from these flat seams, and calculated upon their various thicknesses, is 3 oz. 6 dwt. 16 gr. per ton.

* For this and neighbouring reefs see the author's Report, Dec. 1884.

† Report, Sept. 1884.

There are also auriferous lodes here, transverse to the bedding; one " a nearly vertical reef, consisting of alternate quartz and arenaceous streaks, much decomposed, but presenting the general appearance of a fissure-vein. This lode varies in width from a few inches to several feet, is locally irregular, but upon the whole follows a well-defined course for several hundred yards along the face of the krantz. . . . The stone yields gold at the rate of 18 dwt. 16 gr. to the ton"*.

f'. Still further east is "Mount Joker," where the rocks " consist principally of crystalline false-bedded sandstones overlying a series of shales, which, in turn, rest upon another set of similar sandstones. In the sandstones shales also occur as well as conglomerates, and frequent seams of quartz, some of which, where tested, have been found auriferous" †. " Upon Mount Joker a seam of quartz crops out, or it may be two or more seams, as the rugged nature of the ground renders it difficult to trace the line from one prospecting hole to another. The quartz is bluish-white, much broken up at the outcrop, and contains much oxide of iron and some oxide of manganese. It occurs interstratified between an altered shale (almost a schist) below, and sandstone, also highly altered, above. At the base of the sandstone there is generally a coarse auriferous conglomerate, resting directly upon the quartz, and varying from 6 to 15 inches in thickness. The quartz also varies in its thickness from 2 to 9 inches, the average being about 5 inches." The yield of gold varied from 5 dwt. to 4 oz. 18 dwt. per ton, " equal to an average on this seam (or these seams) of very nearly 1 oz. 7 dwt. to the ton"‡.

g'. On the south of Mount Joker is the farm " De Kuilen," where the beds are similar to those at the lower levels of that mountain, viz. shales, sandstones, and shales, with a westerly dip of from 5° to 7°. From here all along the Spitzkop road only shales are seen, with the exception of intrusive dykes, until near Ross Hill, a few miles west of the Spitzkop mountain. On De Kuilen " a quartz reef can be traced from the head of the small gully, under the marshy ground by the road, rising again beyond the flat." Its yield is estimated at little less than an ounce to the ton. Just beyond where the road passes down a steep incline a quartz-reef occurs, with an estimated yield of not less than 1 oz. of gold to the ton§.

h'. About Ross Hill the rocks become siliceous in character. Sandstones, cherts, and quartzites, previously seen in the deeper valleys, now come to the surface. Here also chalcedolites are seen, but not in great force. The mines of Ross Hill are partly in "rotten-reef" and partly in diorite. I have no definite data respecting the gold-veins here, but they must be rich, as three diggers, after working upon them for about two years, took away 6000 ounces of gold, chiefly derived, I believe, from quartz-leaders in the "rotten-reef." I have seen fine specimens of gold in quartz from these mines.

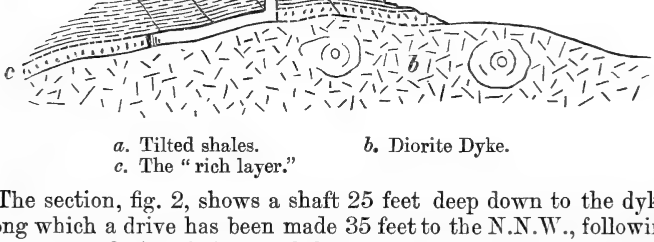
* Report, Sept. 1884.
† Report, Jan. 1885.
‡ Report, Jan. 1885.
§ Report, Feb. 1884.

i'. South of the Spitzkop mountain is "Grey's Creek," near the mouth of which is an old heading, driven 60 feet into the hill. This shows a seam of quartz from 1 foot to 2 feet thick, between decomposed chalcedolite above and brown sand (? decomposed diorite) below. These beds dip W. at an angle of 5°, and underlie the shales that form the high ground on the west. The quartz seam here, interstratified with the beds, varies (where opened) from 1 foot to 2 feet in thickness, and yields an average of 3 oz. 12 dwt. of gold to the ton.

j'. Upon the farm called "Spitzkop," north of the mountain of that name, are numerous cuttings made by the miners, nearly all in shales and flagstones. Towards the east side, however, the more siliceous beds come in, and where exposed in some open mines, they are much decomposed, especially the lower few feet resting upon the saddle of a decomposed diorite dyke. On the east side of the farm the so-called "rotten-reef" has been rather extensively worked in two claims, where it rests upon the saddle-back of a decomposed diorite dyke. The numerous quartz-leaders in the shales "vary even in a few feet from 3 inches to $\frac{1}{2}$ inch in width; they vary slightly also in dip and direction. Their average width may be taken as $1\frac{1}{2}$ inch; their general dip S. 50° to 55°; and general direction E. to W. The direction of the dyke being W.N.W., the leaders strike it at an angle of about 20 degrees."

In the shales are very many thin veins of quartz, more or less vertical, which, in the lower 3 to 5 feet, are broken up and indiscriminately mixed with the matrix, thus forming a so-called "rotten-reef." This term is also applied to the several feet of strata exposed above, although less decomposed.

Fig. 2.—*Section of "Rotten-Reef," Spitzkop.*



a. Tilted shales. *b*. Diorite Dyke.
c. The "rich layer."

The section, fig. 2, shows a shaft 25 feet deep down to the dyke, along which a drive has been made 35 feet to the N.N.W., following the downward dip of the "rich layer," here consisting of 3 feet of "rotten-reef," with from 1 to 2 feet of poorer "wash" between it and the dyke. The shaft is sunk through contorted and partly decomposed shales, with auriferous quartz-leaders.

Three assays made gave :—

No. 1. Quartz, with oxides of iron and manganese, 1 oz. 10 dwt. 11 gr. of gold to the ton of 2000 lb.

No. 2. 3 oz. 6 dwt. 16 gr. of gold to the ton of 2000 lb.

No. 3. 9 dwt. 2 gr. of gold to the ton of 2000 lb.

An open section at Spitzkop shows the upper part, consisting of soft shales, contorted by the irruption of the dyke from below (as in fig. 3), with quartz leaders averaging about six feet apart. Between the shales and the dyke occurs the "rich layer" of black decomposd shale, traversed irregularly in every direction by broken-up veins of quartz. Of this layer, 5 feet thick and conformable to the dyke below, the upper 3 feet are very rich ; it dips N. by. E. into the hill at an angle of 10°. Average samples were taken from this layer by picking down through its whole thickness in several places. The relative proportions by weight were $2\frac{1}{4}$ oz. of decomposed shale and oxide of iron to 1 oz. of quartz. Upon assay, the average sample of the rotten-reef was found to yield 16 dwt. 5 gr. of gold to the ton (2000 lb.).

Other neighbouring sections of "rotten-reef," shales, quartz-leaders, and "pay-dirt," are described in the author's Report, July 1883. "Some shafts are sunk through what appears to be an interstratified mass of decomposed diorite ; if so, it is an intrusion, probably from the main dyke, as the shales are seen dipping under it from either side, and disclose beneath it 2 feet of very rich 'pay-dirt.'" One of these shows :—

3 feet surface-soil.
2 „ rich "pay-dirt."
6 „ decomposed diorite.
16 „ partly decomposed shales with six leaders passed through, the lowest one nearly horizontal.

A similar belt of rocks occurs from Spitzkop down to the Sabie River, where the fine falls by the roadside are slowly cutting their way back in a mass of sandstone, in which their waters have already formed a ravine many hundred yards in length. Thence to the "Mac Mac diggings" similar rocks prevail, indeed all along the level plateau which borders the low country.

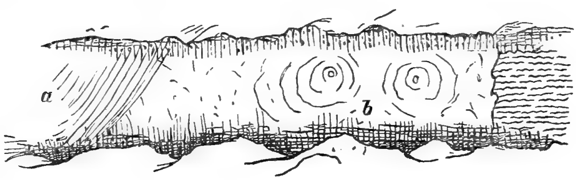
k'. The farms "Lisbon" and "Berlyn," formerly called "Waterfall," are situated on this plateau, and are now being worked by a gold-mining company. The rocks here are shales, occasionally arenaceous ; on the east side are crystalline sandstones, faulted against the shales *. Some of the hills around are capped with chalcedolite. The shales are nearly horizontal, and are intersected at frequent intervals by veins of quartz, varying from 2 to 6 inches in thickness, and dipping at a high angle. These thin veins are auriferous, and appear to be "leaders" from the main quartz-reefs, which run in a nearly N. and S. direction across the property.

* See Geol. Mag., April 1885, p. 171.

The gold lodes consist of main quartz-reefs and transverse leaders; "These leaders are thin (a few inches only in thickness), and consist partly of white quartz, partly of oxide of iron and manganese. Two of them sometimes merge into one, and occasionally two or more unite to form a main lode close to or in contact with the dyke. Almost without exception the gold-mines of this district are in such leaders in proximity to diorite dykes." An average yield of 4 oz. of gold to 2000 lb. of quartz was the estimated result of several examinations.

Several main and branch dykes of diorite are traceable for long distances, and in some instances are well exposed in the open mines. In two cases the shales are sharply tilted by the dykes on the west

Fig. 3.—*Section of Diorite Dyke, Lisbon-Berlyn.*



a. Tilted shale. *b.* Dyke.

side, and in one on the east they are slightly contorted on the other side. In the section the weathering leaves hard kernels of blue diorite with concentric rings, semidecomposed, shading off into the soft brown mass, which otherwise resembles an alluvial loam.

l'. A few miles S.W. of Waterfall are the farms about "Pilgrim's Rest," belonging to the Transvaal Gold-Land-and-Exploration Company. The rocks here are higher in the series and are more siliceous in character, the lower main mass of chalcedolites being in considerable force. Their chief outcrop, however, is along the west side of the Blyde River. Here, also, are many diorite dykes, one of which, a small branch dyke in Pilgrim's-Rest Creek, has tilted the adjacent beds inversely to the usual position. With the exception of the rich alluvial deposits in the creek, the ground chiefly worked here for gold has been the "rotten-reef," similar to those previously described. The chief of these are at Brown's Hill and Ophir Hill; but I have no data upon which to base an opinion as to their value, which is regarded as high.

Crossing the Blyde and mounting the steep escarpment to the west, we find shales cropping out from top to bottom, with the exception of the upper of the two main series of chalcedolites intervening part way up the hill. The shales have generally a small westerly dip, but are locally thrown to high angles and into various positions by plutonic dykes. The chalcedolites are much decomposed, and a bed of quartz, at least one foot in thickness, is seen amongst them. On the summit of the hill is a series of crystalline sandstones.

m'. Just south of the road passing up the escarpment is a piece of ground called "Peach Tree," nearly all on shales, but also with sandstones on the top of the hill. There is on the table-land a highly ferruginous bed, which has been worked by the natives for iron. The shales are intersected by plutonic dykes and by two nearly vertical quartz-reefs, about 12 inches wide, which strike nearly N.E., and yield gold at the rate of upwards of an ounce to the ton.

n'. Following the upper series of chalcedolites a few miles north, we come to "Rotunda Creek," which affords sections at intervals from the top of the hill to the Blyde River; and here we find the rocks following the usual order of the escarpment. Rotten-reefs, containing fine gold, have been worked here. There is also a large main reef, consisting almost entirely of coarse crystals of quartz, and very ferruginous; it is at least 4 feet wide, and yields coarse gold, upon the average not less than 4 oz. to the ton.

o'. Still further north, "Kaspar's Neck" is on shales and quartzites. The lower series of chalcedolites crops out on the east; the upper series in the small valley on the west.

p'. The small stream west of Kaspar's Neck joins the Orighstad River; and in that valley, a few miles above the junction, the rocks are, in ascending order, quartzites and cherts, crystalline sandstones, shales, conglomerates, shales, quartzites, and cherts, all dipping W. at a low angle. In the Orighstad Valley are some highly crystalline sandstones, 40 feet or more in thickness, which yield gold several pennyweights to the ton, as do also the conglomerate beds associated with them.

q'. Towards the head of the Orighstad Valley the rocks are chiefly shales with sandstones, having a well-defined conglomerate at their base, on the hills and ridges. From this point back to Lydenburg the surface is occupied by shales, sometimes arenaceous, which extend almost without intermission to the High Veldt, where they pass beneath the coal-bearing formation. About the head of the Orighstad Valley there are many quartz-reefs, one of which, over 2 feet in width, strikes almost E. for Pilgrim's Rest, and carries gold in the proportion of more than an ounce to the ton.

About the Speckboom River, near the "drifts," are numerous thin veins of quartz, some in diorite, others in shale, all of which, so far as examined, contain more or less gold.

§ 3. Alluvial Auriferous Deposits.

In the Lydenburg goldfields some few patches of very rich alluvial deposits are known; but, considering the great extent of the gold-bearing area, and the quality of the reefs in some places, it is remarkable that no large alluvial field, like those of Australia and California, has yet been discovered. Two years since, when writing of the Kaap goldfields*, I offered some observations on the river-

* Guide to the Goldfields, pp. 51, 57.

valleys and alluvia, and the probable occurrence of gold in those that came from rich quartz-reefs.

Alluvial gold has since been discovered about James Town on the Lampongwana, or Northern Kaap River, and near other streams in the Kaap Valley; still the area of payable ground, as far as thus known, is not sufficiently extensive to support a large digging population. A few of the chief alluvial deposits may be noticed in the same order as the more permanent lodes have been.

e. KaffirSpruit (p. 574).—There is a large quantity of loam, gravel, and similar alluvial deposits, along the margin of the river and spruit, as also in their tributary valleys *. I may add that extensive diggings have been carried on during the last two years, near James Town, with a fair measure of success, in the Lampongwana River.

A digger has secured rights to a large quantity of water (15 heads) from the river above; and as he proposes to bring it to his ground by cutting a race from 15 to 18 miles in length, it is evident that he has found the deposits rich enough to warrant such an undertaking.

In several places along the Kaap rivers, and even up to their sources about the mountains on the west, good alluvial gold has been found.

a'. De Kaap (p. 577).—"In all the creeks good alluvial gold has been found"—at one point in the Kantoor creek "the numerous large nuggets for which the first 'rush' to the Kaap was celebrated"—at another, "several claims were worked with wonderfully good returns." At a spot south-west of the Kantoor "there is a very rich alluvial, yielding a small proportion of reef-gold from the vein just above . . . and large quantities of waterworn gold from the waste of the conglomerates." Work is being carried on in alluvial wash, and from the fact of a long race and a dam having been recently constructed to bring on the water, it may be assumed with very good returns †.

b'. Godwaan Plateau (p. 577), "*Barrett's Rush.*"—About six miles north of the Kantoor is one of the small depressions, falling in a westerly direction, where nuggets were found, just where the road crosses the hollow. The ground here is almost bare sandstone, covered with a few inches only of soil, in which, and amongst the grass roots, the nuggets were discovered.

"*Poverty Creek.*"—"In the main or northern branch of Poverty Creek, some good gold has been found. . . There has been more alluvial ground worked here, in better form and to better advantage, than anywhere else on the plateau. There are two distinct kinds of gold found at this spot, the position of each kind being clearly defined. From this fact and other circumstances it seems probable that two lodes here cross each other or effect a junction" ‡.

"*Willey's Creek.*"—Many nuggets were found here; one that I saw weighed just under a pound.

* See Report, Nov. 1884. † Report, Dec. 1884.
‡ Guide to the Goldfields, p. 55.

d'. *Lydenburg* (p. 578).—At a point on the Dorps River, about half a mile south of the town, good coarse gold has been taken from the gravel bordering the stream; and a large piece was found in gravel along the stream that comes in from the S.E. and near this point joins the Dorps River. "The alluvial deposits around the town are extensive, as well as of considerable depth and richness. The upper part of these deposits consists, in places, of a hard ferruginous 'cement-stone,' or fine gravel cemented by oxide of iron, and containing gold. Beneath this there are several feet of sand and loam, also auriferous, and at the base is an extensive bed of coarse gravel and pebbles, which, wherever it has been tried, has yielded coarse gold, in some places even in payable quantity"*.

h'. At *Ross Hill* (p. 580), as would naturally be expected, the alluvial soil is rich in fine gold.

i'. *Grey's Creek* (p. 581) opens into the same valley as the small stream from Ross Hill, and here both coarse and fine gold occur. On the east side of the creek is a mass of broken quartz in a black sandy soil (apparently the shedding from the contiguous quartz veins in chalcedolite), which is auriferous. Further down the stream good coarse gold occurs in the alluvium.

j'. *Spitzkop* (p. 581).—On the east side of this farm a claim "has been worked down about 15 feet on to the bed-rock, which here consists of shale. At this point there is also an old channel beneath the alluvial ground, which is brown loam, and has hitherto proved rich in gold. The loam carries a small proportion of fine gold throughout, but is, of course, much richer just above the bed-rock; in the old channel especially it has proved very rich, 57 ounces of gold having been taken out (as I am informed) from one paddock, about 36 feet by 45 feet, after three weeks' ground-sluicing" †.

k'. *Berlyn-Lisbon* (*Waterfall*) (p. 582).—The surface of the ground upon and west of Howse's claims, and for some distance to the north and south, is occupied by a terrace of sandy loam. On the opposite side of the river is another terrace, which extends a long distance S., on the west side of a stream; and there is another large patch, bordering another stream that flows into the river east of the Falls. "All this alluvial yields gold" ‡, and is now being removed by hydraulic appliances.

l'. *Pilgrim's-Rest Creek* (p. 583) is occupied from end to end by a mass of coarse gravel and fine loam, the gold from which at one time supported many hundred diggers. The creek is very steep and narrow, and is but three miles or so in length; its containing so much water-worn gold is therefore good evidence of the existence of rich lodes in the immediate vicinity.

m'. *Peach Tree* (p. 584).—Good alluvial ground has been worked in the creek, also upon Columbia Hill, where long races were cut merely for the purpose of sluicing away the surface soil, to the depth of about a foot, for the sake of its gold.

* Report, Dec. 1884. † Report, July 1883.
‡ Report, May 1883.

n'. Rotunda Creek (p. 584).—The alluvial ground has been worked, although not to any great extent *.

q'. Orighstad Valley (p. 584).—Upon the farm "Klipheuvel" there is a "large body of alluvial wash, which covers the part of the farm bordering the stream" †. Good alluvial wash has also been found on the farm "Nauwpoort," a few miles nearer to the head of the valley.

Terraces.—The above notes refer to the alluvial deposits in the bottoms and on the immediate margins of the valleys; but in many instances the terrace-gravels, which are relics of an earlier stage of denudation, are also gold-bearing. In Willey's Creek (*b'*) and at Pilgrim's-Rest Creek (*l'*) are high terraces of rich alluvial wash. I have also observed patches of river-gravel at least 800 feet above the present Speckboom River; but these, so far as I am aware, have not yet been proved auriferous.

§ 4. Gold and Nuggets.

The character of the gold obtained from these fields in the Transvaal varies almost with every locality, whether from the reefs or from the alluvium. Some of the reefs in the Kaap Valley (*a–f*) carry coarse, others fine gold. At De Kaap (*a'*) the gold is fine in the reefs and coarse in the conglomerates; on the Godwaan Plateau (*b'*) the reef-gold is very fine. Near Lydenburg (*d'*) the reefs produce generally rather coarse gold, although some on Paarde-Plaatz (*e'*) is very fine. At Ross Hill (*h'*) and Spitzkop (*j'*) there are large specimens, but the bulk of the gold is very fine; at Lisbon-Berlyn (*k'*) it is coarse, as a rule, with occasional nuggets and some fine gold. Pilgrim's Rest (*l'*) produces fine, and Rotunda Creek (*n'*) coarse gold. In some cases, as at Spitzkop, Pilgrim's Rest, and Ross Hill, the gold is very fine indeed, like flour, of which the grains can scarcely be distinguished even with a lens. This very fine flour-gold seems to be confined to the "rotten-reefs;" the moderately fine to the flat quartz seams; and the coarse to vertical reefs or true lodes.

The gold from the alluvium in the Kaap Valley, as at Kaffir Spruit (*e*), is mostly "scaly" (in small flat pieces), rather pale in colour, not very much waterworn, and with occasional nuggets. At De Kaap (*a'*) it is mostly coarse rich gold, extremely waterworn, having been subjected at least twice to alluvial action—first into the old conglomerates, then from them into the recent deposits. Upon the Godwaan Plateau (*b'*), there is fine as well as coarse gold in the alluvium, the wash having been partly derived from the reefs that carry fine gold. At Lydenburg (*d'*) the wash yields gold of a rather light colour, in scales and grains; about Spitzkop (*h', i', j'*) the gold is of good quality, fine in the wash on the higher lands, and coarse below. At Lisbon-Berlyn (*k'*) it occurs in a similar manner; and at Pilgrim's Rest (*l'*) the gold is very rich, coarse, and with nuggets in abundance.

* See the 'Guide to the Goldfields,' pp. 17, 18. † 'Report,' May 1884.

The following may be given as examples of the occasional rich "finds" in these fields :—

In 1873, at New Caledonia, four large nuggets with a number of smaller ones, collectively weighing 13 lb. 8 oz.

In 1874, at Barrington's claim, a nugget weighing upwards of 87 ounces.

In the same year, nuggets of 48 ounces and 69 ounces were found.

In 1875, at head of Creek, Pilgrim's Rest, one of 8 pounds and another of 57 ounces.

In the same year were found nuggets of 213, 69, 29½, 57, and 47 ounces.

A nugget of 123 ounces was found in a terrace-claim, Upper Creek, at about 30 feet below the surface *.

§ 5. Other Metals and Minerals.

A few other metals and their ores observed in this district are:—

Godwaan Plateau (*b'*).—Silver in the Homeward-Bound Reef.

Here, and also at De Kaap (*a'*), pieces of metal, soft and white, but oxidized on the outside and generally resembling lead in appearance, are frequently found in the gold-washing sluice-boxes of the diggers. I have tested some of these pieces from both places and found them to be zinc. If my tests be supported by others at home, the existence of native zinc will be confirmed.

Paarde Plaatz (*e'*).—In the auriferous quartz seams here the metal platinum occurs, certainly not in large quantity, but fairly constant, in connexion with the gold.

Lydenburg (*d'*).—Good copper-ores, sulphide and carbonate, have been worked here; near the town on the north side, there are extensive old workings, now overgrown; others also are seen near the Speckboom River.

Rotunda Creek (*n'*).—There is rich copper-ore here, both carbonate and black oxide: and grains of native copper have been found in the alluvial gold-washing operations.

Kaap Valley, Welcome Reef (*f*).—There is a large percentage of copper-ore in the quartz here; but no tests have been made of its value.

Argentiferous galena occurs between the goldfields and Pretoria.

Iron in many forms, including hæmatite, is abundant in the Transvaal.

§ 6. The Diorite Dykes.

Frequent mention has been made of the diorite dykes by which this region is traversed, and of the rocks being tilted and otherwise disturbed by their intrusion. There are other points in connexion with them also worthy of notice. Refractory as diorite is in its normal state, it disintegrates much more readily than the softer

* See also 'Guide to the Goldfields,' p. 8.

shales and sandstones through which it often passes; and this fact gives rise to definite physical and surface-features.

Very prominent objects in the immense plains of South Africa, as also indeed amongst the mountains, are the long narrow ridges of what at first sight would appear to be waterworn boulders, but which are really cores from the concentric weathering of diorite dykes. Beneath them the whole of the dyke is often entirely disintegrated into a soft but compact argillaceous mass, passing gradually down into hard unchanged diorite. I have seen a good illustration of this where one of the head streams of the Krokodil River passes through a deep gorge, the almost vertical sides of which expose a good section of decomposed diorite, capped by a mass of rounded cores that spread out beyond the walls of the dyke on either side to some distance. I think the rock weathers more rapidly below the surface; it gets washed away beneath the harder cores, which settle down and accumulate along the line, representing probably several hundred feet of the dyke, gradually weathered and removed by denudation.

When no line of cores has been left, which frequently happens on sloping ground, the course of a dyke may still be traced merely by changes in the vegetation: a greener tint in the grass—which is sometimes quite verdant, whilst that on the shales has been parched to a yellow or brown colour—by lines of bushes, by the growth of different kinds of plants, and so on. Single or parallel lines of dykes may sometimes be detected, even at a great distance.

Where a dyke crosses a watershed from one valley to another, a tributary stream usually cuts its course along the weathered surface into each main valley until the two nearly meet at the watershed, leaving only a narrow "neck" or "pass" between. The rain-collecting area of such necks being reduced to a minimum, they are now subject, as ridges often hundreds of feet above the valleys below, to the least possible action of denudation. A good illustration of this phenomenon is the neck, about a hundred yards wide, at the head of two very deep gorges, one opening north, the other south, just east of the townlands of Lydenburg. On the road to Spitzkop there are four or five such necks (or weathered dykes) almost close together, being perhaps a hundred yards apart, many hundred feet above the ravines, and just wide enough for a waggon-road, with small rounded hills between them; these are called the "Devil's Knuckles."

Discussion.

Mr. C. Thomas said that, having just returned from the country, he was able to state that the goldfield extends beyond the limits mentioned by the Author. It stretches into Swaziland, to the south and east of the district described.

Mr. Bauerman remarked that the occurrence of gold in small quartz-grains immediately associated with diorite masses, as represented in the Author's diagram, was a condition well known in the Ural, Australia, and elsewhere.

44. *On some* Erratics *in the* Boulder-clay *of* Cheshire, *&c., and the* Conditions *of* Climate *they denote.* By Charles Ricketts, M.D., F.G.S. (Read May 27, 1885.)

[Abridged.]

The glacial phenomena in the valley of the Mersey indicate that, though during that period the country was entirely covered with ice and snow, these accumulations were no greater than were derived from the snowfall on the water-slopes of this and its tributary valleys. The glacier-striæ on the surface of the Triassic rocks coincide in direction with those of the respective valleys, or they have a direct reference to the contour of the ground. Taking "Happy Valley" (now Borough Road), Birkenhead, as a typical example, the bottoms of the valleys, where channels have been in pre-Glacial times, are filled to a limited height with irregularly stratified beds of sand and gravel, their presence in other valleys being revealed by excavations and borings for wells, &c.* The sands have been derived from disintegration of the Trias; whilst the pebbles are similar to the erratics so abundant in the Boulder-clay, excepting that all traces of striæ &c. have been removed, it is presumed, by water which, holding sand in suspension, issued from beneath glaciers. On these gravels &c. is situated Boulder-clay containing a much larger proportion of sand and pebbles than the Boulder-clay proper. The flanks of the valleys frequently have rock-surfaces covered with unstratified sands and angular fragments of sandstone, without intermixture of erratic pebbles; they are considered to be moraine accumulations left by glaciers which extended into the sea. The whole is covered with Boulder-clay, a reddish-brown unstratified clay containing pebbles and boulders irregularly dispersed through it.

Besides the accumulations of Triassic fragments already alluded to, others occur at from 125 to 150 feet above ordnance datum, which must have been formed above the then sea-level, and have resulted from the action of strictly local glaciers; one was uncovered a few years ago at the Birkenhead School, and another occurs near the cemetery.

The *clay* of the Boulder-clay may be attributed to the abrasion of adjacent rocks by glaciers, beneath which it issued in subglacier rivers highly charged with mud and sand. Such a condition occurs in Greenland, where the rocks are of granite or of equally indestructible material†; the quantity of sediment must therefore be immensely increased when the strata passed over are so easily disintegrated as the Trias and Coal-measures. The water being

* "Buried Valley of the Mersey," by T. Mellard Reade, C.E., F.G.S. (Proc. Liverpool Geol. Soc. 1872–73, p. 42).

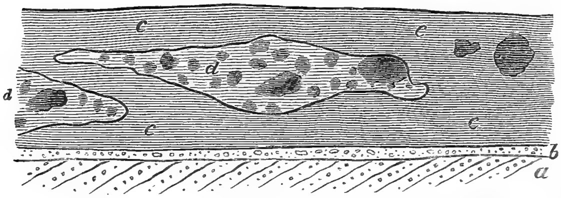
† "Physics of Arctic Ice," by Dr. Robert Brown, F.R.G.S. (Quart. Journ. Geol. Soc. vol. xxvi. p. 682).

thus surcharged with mud may account for the entire absence of marine life; fractured, rarely perfect, shells occur sparsely scattered in the clay, but never under such circumstances that it could be imagined they had lived where found.

The pebbles and boulders imbedded in the clay, and from which the formation derives its name, consist of fragments of hard rock from the size of minute grains to two or three feet or more in diameter, such as may have been derived from lands encompassing the Bay of Liverpool and the adjoining portion of the Irish Sea—from Cumberland, the south-west of Scotland, the north and east of Ireland, and North Wales. Their surfaces are very generally flattened, smoothed, and polished, and a large proportion are covered with striæ, grooves, and scratches, universally acknowledged to have been caused by abrasion beneath glaciers. If it is conceded that they have dropped into the clay from floating ice, their number is such as would indicate that the whole bay was sufficiently packed with bergs and floes to prevent altogether the formation of waves *, and therefore, in the absence of other currents, no evidences of stratification are afforded.

Amongst the erratics in the Boulder-clay may be included masses of unconsolidated sands and gravels, often alluded to by local geologists as "pockets of sand," &c. The materials resemble accumulations already referred to as situated in the bottoms of valleys as a bed upon which the Boulder-clay reposes; their general shape is comparable to that of the section representing masses containing a remarkable collection of dark green blocks of disintegrated traps, unmixed with other boulders, exposed in 1878 during the construction of the Bootle Docks (fig. 1). These were imbedded in a

Fig. 1.—*Section in Bootle Docks, Liverpool.*
(Length about 28 feet.)



a. Trias. *b.* Gravel. *c.* Boulder-clay.
d. Masses containing disintegrated Trap.

light green sandy matrix, and formed accumulations which were very conspicuous, the colour being in marked contrast to that of the Boulder-clay; their disintegration must have been due to the same

* "However great the agitation of the sea may be in the open ocean, and though it may dash its waves with wild fury on the edge of the ice, within the ice-girdle it is undisturbed" ('New Lands within the Arctic Circle,' by Lieut. Julius Payer: chap. i. § 23).

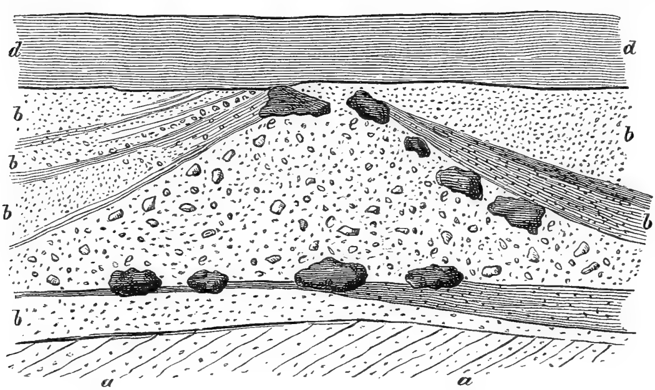
In January 1881 the Mersey was covered with floating ice, or rather snow, for nearly its whole width; on the waves reaching the ice they terminated in a swell for a short space, whilst inside the surface was perfectly unmoved.

causes as that of some boulders of granite and trap to be alluded to hereafter.

When brick-making was in progress behind the Mission House in Borough Road, Birkenhead, several blocks (five or six) of sand and clay were exposed; they contained a few erratic pebbles as well as bands, an inch or so thick, of vegetable mould. In one the clayey and carbonaceous beds were doubled on themselves, being so bent at the flexure as to squeeze away the clay. In this case also the loose sand has fallen away and spread from the mass as it settled down in the Boulder-clay. One piece exhibited spots of carbonaceous matter, which are probably the rootlets of plants; these are the only examples of vegetable life met with in the Boulder-clay*. Being in close proximity to each other, they probably all dropped from the same iceberg stranded at this spot. The only locality affording evidence of vegetation, *in situ*, during the Glacial Period is at Leighton Hall, Yealand, Lancashire; it occurs as a band, ten or twelve inches thick, of Carboniferous-Limestone pebbles, each of which is covered with an intensely black carbonaceous powder; this bed separates a lower from an upper portion of an accumulation forming a moraine mound, and indicates the recession, for a series of years, of the glacier by which the mound was formed.

Blocks of the Boulder-clay itself, which would escape notice should they occur in the Boulder-clay proper, in consequence of its identity with them, have been frequently observed in those stratified sands and gravels, previously referred to, which cover the bottoms of preglacial valleys such as Happy Valley (fig. 2); similar blocks

Fig. 2.—*Section in Happy Valley, Birkenhead.* (Height 10 feet.)



a. Trias. *b*. Sand. *c*. Gravel. *d*. Boulder-clay.
e. Blocks of Boulder-clay in gravel and sand.

* Mr. D. Mackintosh, F.G.S., found plant-remains in the Boulder-clay near Crewe; and Mr. T. Ward of Northwich presented me with a fragment of wood obtained at a depth of 35 feet in undisturbed Boulder-clay.

also occur in the sandy Boulder-clay which immediately overlies these sands and gravels. Mr. A. Strahan, F.G.S., of H.M. Geological Survey, informs me that he has observed them under similar conditions in other places.

It is more particularly desired to direct attention to the occurrence of other boulders which frequently bear evidence of glacier-action, and have also been exposed to other influences before they were floated away and dropped into the clay. Some, of granite, are weathered all over, their entire surface being roughened and so far disintegrated that fragments can be broken off by the fingers *; others in the same state have also had a portion split off. Some, having their surfaces glaciated, crumble into fragments by slight pressure; whilst others cannot be removed without separating into their component crystalline particles, though when *in situ* each granule retains its relative position, and a careful removal of the clay may even show their surfaces to be smoothed and polished.

A somewhat similar kind of weathering is often observed in various kinds of volcanic rock. In some it peels off in concentric laminæ; where this disintegration has not penetrated the whole mass, the central nucleus remains solid and unaffected. Examples of a different kind are frequent in which the mass is disintegrated throughout, being easily crushed or broken and the granules separated. The striæ formed previous to weathering in a few cases remain visible.

Mr. G. H. Kinahan, of H.M. Geological Survey of Ireland, has informed me that blocks of disintegrated granite are frequent in the glacial deposits, especially those of Wicklow and south-east Wexford, being more prevalent in moraine-drift than in the Boulder-clay. There are granite boulders, imbedded in moraine accumulations, near Shap, Westmoreland, which have become disintegrated in various degrees, and to an extent as great as those occurring in the Boulder-clay of Cheshire, whereas at the present time the Shap granite, both in the well-known blocks and *in situ*, weathers only on the exterior.

What Mr. Kinahan states respecting the granite boulders of Co. Wicklow is equally applicable to some of volcanic origin in the glacial deposits of Co. Antrim, where they occur in every stage of disintegration, but modified according to their structure. Examples are met with in moraine- and esker-mounds, and in the Boulder-clay, exactly corresponding with some in the Boulder-clay of Cheshire.

Rocks of various kinds are coated with a powder, derived from their disintegration, generally of a light-green colour, having mixed with it minute fragments of the same. In some, the general surface of which affords proof of glacial erosion, channels or hollows have been formed subsequently, these being filled with similar disintegrated materials. In other instances the weathering has so

* The condition of these granite blocks coincides with the account given of some in Spitzbergen and Sweden, "split up whilst *in situ* by the action of the frost" ('Arctic Voyages of Prof. Nordenskiöld,' by Alex. Leslie, p. 233).

extended throughout the whole substance that, on removal, they break up entirely.

A large proportion of Carboniferous-Limestone pebbles bear evidence of atmospheric and chemical erosion in a variety of ways. Occasionally they are weathered all over, and portions of organisms stand in relief; more frequently they are eroded in the same way over a considerable surface, whilst the remainder continues intact, with its ice-marks unaffected. A frequent feature is the formation of channels or hollows in the blocks; this occurs without affecting other portions, which may still retain marks of glaciation. This weathering of limestone appears as if caused by chemical erosion; but the results so resemble those of other rocks to which this theory cannot apply, that it is rendered doubtful whether it can be entirely accounted for by that cause. In many instances limestone pebbles have been split into fragments which are occasionally in apposition, but being generally obtained from stone-heaps, they are more frequently detached. A glaciated one found *in situ* in the Boulder-clay is split into four fragments, which remain in apposition; the split surfaces, as well the outer portion close to them, have subsequently been somewhat eroded since their fracture.

It is evident that these various forms of weathering have occurred subsequently to glacier-action; and an examination of what is now in progress fails to explain these peculiar phenomena. It is only in Carboniferous-Limestone pebbles contained in morainic accumulations that examples occur similar to, and even identical with, those found in the Boulder-clay.

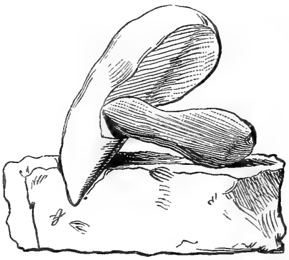
Several pebbles of limestone are not only glaciated, but also perforated by mollusca and sponges; as a rule, no shells are retained in the cavities. There is generally, if not always, evidence that the borings have been made subsequently to glaciation. In some instances they have afterwards also been again exposed to glacial friction, and fragments have likewise been broken off prior to their deposition in the clay. In two instances glaciated and perforated blocks were found to be afterwards weathered, one over the perforated surface, the other as a channel-like groove on the portions covered with striæ. A solitary example of borings in softer limestone (it may be of Antrim chalk) contains many shells entire, and its surface is covered with *Serpulæ*.

A very frequent form of weathering in stratified, slaty, and other rocks is produced by their splitting into pieces, the surfaces thus formed having undergone little, if any, change; the fragments are more frequently detached and separated, but sometimes are in exact apposition; or, when split into many parts, some may be contiguous, whilst others belonging to the same pebble are absent. Occasionally, but necessarily very rarely, pebbles have the split fragments separated for a small space, having fallen from each other as they dropped into the clay. In a glaciated one of Silurian sandstone found at Little Eye, Hilbre (an island at the mouth of the Dee), the fragments were an inch and a half from each other with their relative position changed. Another, at Rock Ferry, had the

greater axis somewhat removed from the perpendicular with a small detached portion lying nearly at a right angle to its original position, the thinner and lower part not being entirely displaced, through resting on a slight projection at the lower end of the fracture (fig. 3).

Similar glaciated pebbles "split and shattered by the frost" into fragments which still remain exactly in apposition are, in many districts, buried in moraine accumulations formed on land. These fractures must have occurred subsequently to the envelopment of the blocks in glaciers, otherwise the pieces could not have continued so accurately in position whilst moving beneath such a burden.

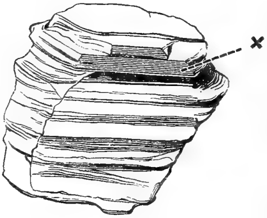
Fig. 3.—*Silurian pebble split, separated, and displaced, as* in situ *in Boulder-clay, Rock Ferry.* (One third natural size.)



Some erratics are so sculptured into forms dependent on differences in their texture, that the less easily disintegrated portions, and the harder materials filling shrinkage-joints, stand prominently in relief; some are so fashioned and modelled that every bed, however thin, is conspicuous. There exists a great similarity between some such specimens from the Boulder-clay and others in moraine accumulations (compare figs. 4–7). This is remarkably the case with two from a

Fig. 4.—*Weathered block from Boulder-clay.* (One third natural size.)

Fig. 5.—*Weathered block with smoothed surfaces from Boulder-clay.* (One third natural size.)



×. Smoothed surfaces.

moraine mound at Leighton Hall; and another, of fantastic shape, is hardly distinguishable from an example near Shap, whilst others of a similar kind bear a striking resemblance to each other.

Fig. 6.—*Weathered block from Moraine.* (One third natural size.)

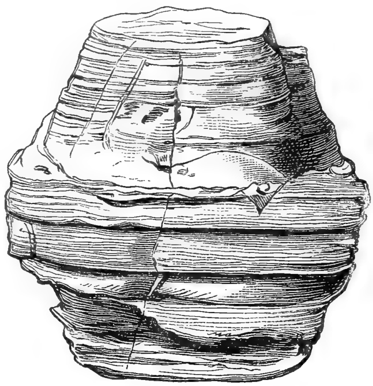


Fig. 7.—*Weathered block from Moraine.* (One third natural size.)

Several blocks, subsequently to being weathered, have had portions of their surface rubbed; this generally occurs over a very limited space, and leaves adjoining and even more prominent parts entirely untouched (fig. 5). No example has yet been found in moraines; but it may be concluded that this attrition could not have been caused by propulsion along the rock-surface over which the glacier moved. It is more probable that, carried forward by an accumulating glacier, thin pebbles have rubbed against others imbedded in the same moraine-heap.

Pieces of flint occur in the Boulder-clay, but they are rare. Some have had flakes forcibly broken off, it may be several from the same specimen: occasionally the depression is formed which is the counterpart to the "bulb of percussion;" and at this point the flint is sometimes crushed as if from the intensity of the pressure by which a flake has been splintered off. In others the more prominent and rounded portions of the nodules bear evidence of being rubbed and chipped as by a grinding motion under pressure. There are none which have been rounded by the rolling motion caused by waves or currents.

The rarity of flints in the Boulder-clay is not surprising if it is considered that they have been carried into the Bay of Liverpool by means of icebergs and floes which ploughed their way across through closely packed ice, distributing their load of boulders in the passage; even in the glacial accumulations in the neighbourhood of Belfast, in close proximity to the Chalk formation, they are not found to be very abundant. Many of the flints in the Eskers and

in the Boulder-clay near Belfast have chips and flakes broken off, and the resulting angles crushed in a similar manner to some in the Boulder-clay of Cheshire and Lancashire. The most probable explanation of the separation of the chips and flakes is that the flints, whilst enveloped in glaciers, passed over the platforms formed of layers of flints so constantly interstratified with the Chalk or White Limestone of Co. Antrim.

The peculiar instances of weathering which rocks of different kinds have undergone prior to their deposition in the Boulder-clay appear to have escaped notice almost entirely, with the exception of blocks of disintegrated granite and trap; these are too conspicuous to be overlooked. The consideration of all these phenomena tends to prove that, during the glacial period, though the climate was always of an arctic character, with perennial snow resting on the ground, there were frequent variations in the severity of the seasons—that a less amount of snow fell during one series of years than during another, so that for a considerable time glaciers receded, leaving the contents of moraines exposed to vicissitudes of the weather, to repeated successions of frost and thaw, probably recurring daily during several months in the year. Again they increased in size and carried forward the accumulations as an integral part of their volume, so that they eventually reached the sea, and icebergs were formed, "forced off from their parent glaciers by the buoyant action of the sea" and floated away. They cannot be considered to represent an interglacial period such as the examination of certain deposits in Scotland and elsewhere is supposed to indicate; for these weathered erratics are found in all situations in the Boulder-clay. The changes in climate which took place appear to have been not unlike those which occur in Greenland, where it is recorded that the glaciers have been observed to successively recede and advance to the extent of several hundred yards *. In some respects they may be compared to changes of climate in our own country, where some winters are mild and others severe, some remarkable for abundance of rain or snow, others for frost and fine weather.

Discussion.

Dr. Evans thought the observations of Dr. Ricketts were of very great interest, whatever interpretation was put upon them.

Dr. Hicks asked if it were not possible that some of the changes indicated were due to the percolation of water through the sandy boulder-clays.

The Author, in reply, said the evidence was entirely in favour of the decomposition having taken place before the imbedding of the fragments.

* "On the Ice-fjords of North Greenland," by Amund Helland, of Christiania (Quart. Journ. Geol. Soc. vol. xxxiii. p. 154).

GENERAL INDEX

TO

THE QUARTERLY JOURNAL

AND

PROCEEDINGS OF THE GEOLOGICAL SOCIETY.

[The fossils referred to are described; and those of which the names are printed in italics are also figured.]

END OF VOL. XLI.

Printed by TAYLOR and FRANCIS, Red Lion Court, Fleet Street.

PROCEEDINGS

OF THE

GEOLOGICAL SOCIETY OF LONDON.

SESSION 1884–85.

November 5, 1884.

Prof. T. G. Bonney, D.Sc., LL.D., F.R.S., President, in the Chair.

William Lower Carter, Esq., B.A., Emmanuel College, Cambridge, was elected a Fellow of the Society.

The Secretary announced that a water-colour picture of the Hot Springs of Gardiner's River, Yellowstone Park, Wyoming Territory, U.S.A., which was painted on the spot by Thomas Moran, Esq., had been presented to the Society by the artist and A. G. Renshaw, Esq., F.G.S.

The List of Donations to the Library was read.

The following communications were read:—

1. "On a new Deposit of Pliocene Age at St. Erth, 15 miles east of the Land's End, Cornwall." By S. V. Wood, Esq., F.G.S.

2. "The Cretaceous Beds at Black Ven, near Lyme Regis, with some supplementary remarks on the Blackdown Beds." By the Rev. W. Downes, B.A., F.G.S.

3. "On some Recent Discoveries in the Submerged Forest of Torbay." By D. Pidgeon, Esq., F.G.S.

The following specimens were exhibited:—

Specimens exhibited by Searles V. Wood, Esq., the Rev. W. Downes, B.A., and D. Pidgeon, Esq., in illustration of their papers.

A worked Flint from the Gravel-beds (? Pleistocene) in the Valley of the Tomb of the Kings, near Luxor (Thebes), Egypt, exhibited by John E. H. Peyton, Esq., F.G.S.

Specimens of *Voluta Lamberti* from the Coralline Crag, and of *Cyprina angulata* from the Blackdown beds, exhibited by W. H. Dalton, Esq., F.G.S. Upon these specimens the following note by Mr. Dalton was read:—"The attention of the Society being directed to the Blackdown beds, it may be worth while to note a peculiar feature in the specimen exhibited of *Cyprina angulata,* Fleming, belonging to the Museum of Practical Geology, and brought here to-night by the kind permission of the Director-General of the Geological Survey.

"The valve, lying with its concavity downwards, has but partially imbedded itself in the sediment, and in subsequent silicification a film of chalcedony has been deposited on the free surface of the matrix within the shell.

"Similar surfaces are shown by the casts of *Voluta Lamberti*, Sowerby, also here exhibited, from the collection of Mr. H. Stopes, F.G.S. These were found in a small quarry of the Coralline Crag rock-bed at Aldborough. They show that as the shells lay on the sea-bed, the upper part of each whorl was occupied by gases arising from the decomposition of the animal, to the exclusion of the calcareous mud, which could only rise to the crest of the arch of each successive suture. Its surface within the shell was not a plane, like that of the Blackdown specimen, but shows, for each whorl, an upward bulge in the centre, an annular depression near the edge, and a rise from this hollow to the interior surface of the shell, indicating the effect of alternating pressures (probably tidal) acting, through the mouth of the shell, on the elastic cushion of imprisoned gases, which would have escaped by the spiral, had the shells been rolled over two or three times only by currents."

November 19, 1884.

Prof. T. G. Bonney, D.Sc., LL.D., F.R.S., President, in the Chair.

Nicol Brown, Esq., 34 Canonbury Park, N.; James Charles Chaplin, Esq., 10 Earl's Court Square, S.W.; Herbert W. Hughes, Esq., Assoc. R.S.M., Priory Farm House, Dudley; and Rev. Samuel Pilling, Osborne Terrace, Regent Road, Blackpool, were elected Fellows; Professor A. L. O. Descloizeaux, of Paris, a Foreign Member; and Professor Hermann Credner, of Leipzig, a Foreign Correspondent of the Society.

The List of Donations to the Library was read.

The following communications were read:—

1. "Note on the Resemblance of the Upper Molar Teeth of an Eocene Mammal (*Neoplagiaulax*, Lemoine) to those of *Tritylodon*." By Sir Richard Owen, K.C.B., F.R.S., F.G.S.

2. "On the Discovery in one of the Bone-caves of Creswell Crags of a portion of the Upper Jaw of *Elephas primigenius*, containing, *in situ*, the first and second Milk-molars (right side)." By A. T. Metcalfe, Esq., F.G.S.

3. "Notes on the Remains of *Elephas primigenius* from one of the Creswell Bone-caves." By Sir R. Owen, K.C.B., F.R.S., F.G.S., &c.

4. "On the Stratigraphical Positions of the *Trigoniæ* of the Lower and Middle Jurassic Beds of North Oxfordshire and adjacent districts." By Edwin A. Walford, Esq., F.G.S.

The following objects were exhibited:—

Micro-photographs, illustrating secondary structures in some Sutherland rocks, exhibited by J. J. H. Teall, Esq., F.G.S.

A specimen of Silver Glance incrusting Calcite, from Rabbit Mountain, Lake Superior, exhibited by H. Bauerman, Esq., F.G.S.

A new substage Condenser for the Microscope, exhibited by Dr. G. C. Wallich.

Specimens exhibited by Messrs. Metcalfe and Walford, in illustration of their papers.

December 3, 1884.

Prof. T. G. Bonney, D.Sc., LL.D., F.R.S., President, in the Chair.

Walter Henley Bartlett, Esq., F.R.A.S., 4 Great George Street, Westminster, S.W.; Thomas Brook, Esq., Assoc. M. Inst. C.E., Hartley, Kirkburton, near Huddersfield; Charles Ziethen Bunning, Esq., Warora, Central Provinces, East Indies; Thomas Edward Candler, Esq., Canton Club, Canton, China; Orville Adelbert Derby, Esq., Rio de Janeiro, Brazil; Colin Docwra, Esq., Balls Pond Road, N.; Charles Eastwood, Esq., Linacre Works, Bootle, Liverpool; Frank Lynwood Garrison, Esq., 1523 Girard Avenue, Philadelphia, U.S.A.; Richard Charles Hills, Esq., 448 Welston Street, Denver, Colorado, U.S.A.; Frank Johnson, Esq., Rio Tinto, and 379 Euston Road, N.W.; Sir Herbert Eustace Maxwell, Bart., M.P., Monreith, Whauphill, N.B.; W. J. E. de Müller, Esq., Landhof, Bern, Switzerland; James Sterling, Esq., F.L.S., District Surveyor, Omeo, Victoria; Thomas Henry Ward, Esq., E.I.R. Collieries, Giridih, Bengal; Rev. Brownlow J. Westbrook, Greymouth, New Zealand; and W. Hoffman Wood, Esq., 14 Park Square, Leeds, were elected Fellows of the Society.

The List of Donations to the Library was read.

The Secretary announced that the following specimens had been presented to the Society's Museum:—

Specimens illustrating a paper on the Serpentines of Porthalla Cove (Q. J. G. S. vol. xl. p. 458), presented by the author, J. H. Collins, Esq., F.G.S.

Two slides with Cretaceous Lichenoporidæ, illustrating a pap in the Q. J. G. S. vol. xl. p. 850, presented by the author, G. R. Vin Esq.

Specimens of Fossil Bryozoa from Muddy Creek, Victoria, presented by J. Bracebridge Wilson, Esq., of Geelong.

Casts of Footprints in the Lower New Red Sandstone of Penrith, illustrating a paper in the Q. J. G. S. vol. xl. p. 479, presented by the author, G. Varty Smith, Esq., F.G.S.

The President announced the great loss which the Society had sustained in the decease of Mr. R. A. C. Godwin-Austen, F.R.S., which took place at his country seat, Shalford House, near Guildford, on the 25th November, in his 76th year. He became a Fellow of the Society in the year 1830, so that he had belonged to it for 54 years. For three years he filled the office of Foreign Secretary; he had been a Vice-President and an active Member of the Council; but he always refused to be nominated as President, although several times urged to accept that honour. He was a Wollaston Medallist and the author of sixteen papers in the Society's publications. His writings were remarkable for their clear and masterly character, and displayed that peculiar insight into geological structure which almost amounts to foresight.

The following communications were read:—

1. "Note on a Section near Llanberis." By Professor A. H. Green, F.G.S.

2. "The Tertiary Basaltic Formation in Iceland." By J. Starkie Gardner, Esq., F.L.S., F.G.S.

3. "On the Lower Eocene Plant-beds of the Basaltic Formation of Ulster." By J. Starkie Gardner, Esq., F.L.S., F.G.S.

The following objects were exhibited:—

Rock-specimens and Microscopic Sections, exhibited by Prof. A. H. Green, F.G.S., in illustration of his paper.

Specimens, exhibited by J. S. Gardner, Esq., F.G.S., in illustration of his paper.

Specimens from Iceland, exhibited by Prof. J. W. Judd, F.R.S., Sec. G.S., in illustration of Mr. Gardner's paper.

A photograph of *Palæophoneus nuncius*, Torell and Lindström, from the Upper Silurian of the Isle of Gotland, exhibited by Dr. H. Woodward, F.R.S., F.G.S.

Clay Ironstone Slabs from the Forest-bed of Happisburgh, exhibited by E. T. Newton, Esq., F.G.S.

December 17, 1884.

W. Carruthers, Esq., F.R.S., Vice-President, in the Chair.

David Llewellin Evans, Esq., The Gold Tops, Newport, Monmouthshire, was elected a Fellow of the Society.

The List of Donations to the Library was read.

The following communications were read:—

1. "On the South-western Extension of the Clifton Fault." By Prof. C. Lloyd Morgan, F.G.S., Assoc. R.S.M.

2. "On the Recent Discovery of Pteraspidian Fish in the Upper Silurian Rocks of North America." By Prof. E. W. Claypole, B.A., B.Sc. (Lond.), F.G.S.

3. "On some West-Indian Phosphate Deposits." By George Hughes, Esq., F.C.S. (Communicated by W. T. Blanford, Esq., LL.D., F.R.S., Sec. G.S.)

4. "Notes on species of *Phyllopora* and *Thamniscus* from the Lower Silurian Rocks, near Welshpool, Wales." By George Robert Vine, Esq. (Communicated by Prof. P. Martin Duncan, F.R.S., F.G.S.)

Specimens and photographs were exhibited by George Hughes, Esq., F.C.S., in illustration of his paper.

January 14, 1885.

Prof. T. G. Bonney, D.Sc., LL.D., F.R.S., President, in the Chair.

Ewan Cameron Galton, Esq., B.A., Shelsley Grange, Worcester; Henry Brougham Guppy, Esq., M.B. Edinb., R.N., Surgeon on Board H.M.S. 'Lark,' 17 Wood Lane, Falmouth; Henry G. Hanks, Esq., State Mineralogist, California State Mining Bureau, San Francisco; and William Elliott Howe, Esq., Matlock Bath, Derbyshire, were elected Fellows of the Society.

The List of Donations to the Library was read.

The following communications were read :—

1. "The Metamorphism of Dolerite into Hornblende-schist." By J. J. Harris Teall, Esq., M.A., F.G.S.

2. "Sketch of the Geology of New Zealand." By Captain F. W. Hutton, F.G.S., Professor of Biology in the Canterbury College, University of New Zealand.

3. "The Drift-deposits of Colwyn Bay." By T. Mellard Reade, Esq., F.G.S.

The following objects were exhibited :—

Life-sized photographs of the fruit of the recent Cycads, *Encephalartos latifrons* and *E. longifolius*, from South Africa, exhibited by Prof. W. T. Thiselton Dyer, F.R.S.

Objects shown with simple illumination, dark-ground illumination, and polarized light, by means of Dr. Wallich's new Condenser, exhibited by Dr. G. C. Wallich.

Specimens and microscopic rock-sections, exhibited by J. J. H. Teall, Esq., F.G.S., in illustration of his paper.

January 28, 1885.

Prof. T. G. Bonney, D.Sc., LL.D., F.R.S., President, in the Chair.

Frederick John Cullis, Esq., 28 Claremont Road, Handsworth, Birmingham; Henry Dewes, Esq., 19 Duchess Road, Edgbaston, Birmingham; Henry Hutchins French, Esq., Grove Road, Sutton, Surrey; Jacob Hort Player, Esq., F.C.S., Calthorpe Road, Birmingham; and the Honourable Donald A. Smith of Montreal were elected Fellows, and Professor F. Fouqué of Paris and Dr. Gustav Lindström of Stockholm, Foreign Correspondents of the Society.

The List of Donations to the Library was read.

The President called attention to the great loss the Society had sustained in the sudden and unexpected death of Dr. J. Gwyn Jeffreys, F.R.S., &c., who had been for twenty-one years continuously a Member of the Council, and for fourteen years of that time had performed most valuable services to the Society as Treasurer.

The following communications were read :—

1. "The Boulder-Clays of Lincolnshire: their Geographical Range and Relative Age." By A. J. Jukes-Browne, Esq., B.A., F.G.S.

2. "On the Geology of the Rio-Tinto Mines, with some general remarks on the Pyritic Region of the Sierra Morena." By J. H. Collins, Esq., F.G.S.

3. "On some new or imperfectly known Madreporaria from the Great Oolite of the Counties of Oxford, Gloucester, and Somerset." By R. F. Tomes, Esq., F.G.S.

Specimens of Flint implements were exhibited by John Evans, Esq., LL.D., F.R.S., F.G.S.

February 11, 1885.

Prof. T. G. Bonney, D.Sc., LL.D., F.R.S., President, in the Chair.

Arthur William Clayden, Esq., M.A., North Lodge, Bath College, Bath; Samuel Rideal, Esq., B.Sc. (Lond.), F.C.S., Devon Lodge, Mayow Road, Forest Hill, S.E.; and H. W. Williams, Esq., Solva, Pembrokeshire, were elected Fellows of the Society.

The List of Donations to the Library was read.

The following communications were read :—

1. "The Tertiary and Older Peridotites of Scotland." By Prof. John W. Judd, F.R.S., Sec.G.S.

2. "Boulders wedged in the Falls of the Cynfael, Ffestiniog," By T. Mellard Reade, Esq., F.G.S.

[Abstract.]

This paper briefly described certain phenomena of stream-denudation observed in the bed of the Cynfael, which has cut a deep channel through the Lingula Flags, the course of the channel being mainly dependent on the jointing of the rock. In one spot the upper beds at the top of the gorge have slid upon the lower along their dip, about 10° to north by east, so as to project over the stream like a corbel; and advantage has been taken of this to form a bridge by means of a slab of rock laid from the projecting mass to the top of the opposite bank. At another point several very large

boulders are wedged fast in the channel, and suspended over the stream, which flows about 6 feet beneath them. The boulders could not possibly have been carried down the existing gorge, and they did not, the author believed, fall from above. He suggested that they might have been carried down by the aid of ice, probably in the glacial period, when the stream ran in a wider channel at a higher level, and that the stream had since deepened its bed at least 6 feet below them.

The following objects were exhibited:—

Rock-specimens and Microscopic Sections, exhibited by Prof. J. W. Judd, F.R.S., in illustration of his paper.

Platinotype Photographs of Views in various parts of England, illustrating the features of the different Geological Formations, exhibited by R. H. Tiddeman, Esq., F.G.S.

ANNUAL GENERAL MEETING,

February 20, 1885.

Prof. T. G. Bonney, D.Sc., LL.D., F.R.S., President, in the Chair.

Report of the Council for 1884.

In presenting their Report for the year 1884, the Council of the Geological Society regret to have to state that the improvement which they thought might be recognized in the position of the Society when they drew up their last Annual Report has not been maintained. They can only once more express the hope that this state of things is due chiefly, if not entirely, to the wide-spread depression which still prevails, and that in the course of a year or two a revival of the general prosperity of the country may place the affairs of the Society once more upon a satisfactory footing.

The number of Fellows elected during the year is only 48, of whom 34 paid their fees before the end of the year, making, with 9 previously elected Fellows who paid their fees in 1884, a total accession during the year of only 43 Fellows. Against even this small number we have to set the loss by death of 32 Fellows, and by resignation of 18 Fellows, while 8 Fellows were removed from the list for non-payment of contributions, making a total loss of 58 Fellows. There is thus a decrease of 15 in the number of Fellows. Of the 32 Fellows deceased 6 were compounders, and 7 non-contributing Fellows, and as 1 non-contributing Fellow became Resident, and another resigned, the number of contributing Fellows is reduced by 6, being now 816.

The total number of Fellows and Foreign Members and Correspondents was 1434 at the close of the year 1883, and 1420 at the end of 1884.

At the end of the year 1883 there were 2 vacancies in the list of Foreign Members; and during 1884 intelligence was received of the decease of 2 Foreign Members. Four Foreign Members were elected during the year to fill up these vacancies.

In the list of Foreign Correspondents there was 1 vacancy at the close of 1883, and intelligence was received of the death of 2 more during the year 1884. These losses, with the filling up of the above-mentioned vacancies in the list of Foreign Members, pro-

duced in all 7 vacancies in the list of Foreign Correspondents, 5 of which were filled up during the year. Thus at the close of the year 1884, the list of Foreign Members was complete, and there were 2 vacancies in that of the Foreign Correspondents of the Society.

The total Receipts on account of Income for the year 1884 were only £2527 1*s.* 8*d.* being £87 9*s.* 5*d.* less than the estimated Income for the year. The total Expenditure, on the other hand, amounted to £2699 17*s.* 6*d.*, or £109 13*s.* more than the estimated Expenditure for the year. The excess of the Expenditure over the Income of the year was therefore £172 15*s.* 10*d.*

Out of the Balance in the Society's hands at the beginning of 1884, the Council have invested the sum of £100 in the purchase of £99 0*s.* 2*d.* Consols.

The Council have to announce the completion of Vol. XL. and the commencement of Vol. XLI. of the Society's Quarterly Journal.

The Council have also to announce that a valuable picture of the Hot Springs of Gardiner's River, Yellowstone Park, painted on the spot by T. Moran, Esq., has been kindly presented to the Society by that gentleman and A. G. Renshaw, Esq., F.G.S.

The Council have awarded the Wollaston Medal to George Busk, Esq., F.R.S., F.G.S., in recognition of the valuable services he has rendered to Geological Science by his long-continued researches among the Recent and Fossil Polyzoa, and the Mammalia of the Post-Tertiary deposits.

The Murchison Medal, with the sum of Ten Guineas from the proceeds of the Fund, has been awarded to Dr. Ferdinand Römer, For. Memb. G.S., in testimony of appreciation of his researches in Palæontology and Stratigraphical Geology, especially among the rocks of Palæozoic age, in both the Old and the New World.

The Lyell Medal, with the sum of Forty Pounds from the proceeds of the Fund, has been awarded to Professor H. G. Seeley, F.R.S., F.G.S., in recognition of his numerous and valuable contributions to Vertebrate Palæontology and General Geology, and to aid him in the further prosecution of his researches.

The Bigsby Medal has been awarded to M. Alphonse Renard, For. Corr. G.S., in token of appreciation of the great value of his petrographical researches among the older formations of Belgium, and his studies of the nature and origin of Deep-sea Deposits.

The balance of the proceeds of the Wollaston Donation Fund has been awarded to Dr. Charles Callaway, F.G.S., in recognition of the value of his investigations among the Archæan rocks, and to aid him in the further prosecution of his researches.

The balance of the proceeds of the Murchison Geological Fund has been awarded to Horace B. Woodward, Esq., F.G.S., in testimony of appreciation of his critical study of the Geology of England and Wales, and to aid him in completing his accurate digest of information upon the subject.

The balance of the proceeds of the Lyell Geological Fund has been awarded to A. J. Jukes-Browne, Esq., F.G.S., in recognition of the

value of his investigations concerning the subdivisions of the Cretaceous Rocks of this country, and to aid him in their further prosecution.

Report of the Library and Museum Committee.

Library.

Since the last Anniversary Meeting a great number of valuable additions have been made to the Library, both by donation and by purchase.

As Donations the Library has received about 219 volumes of separately published works and Survey Reports, and about 300 Pamphlets and separate impressions of Memoirs, besides about 134 volumes and 148 detached parts of the publications of various Societies, and 16 volumes of independent Periodicals presented chiefly by their respective Editors, and also 16 volumes of Newspapers of various kinds. This will constitute a total addition to the Society's Library, by donation, of about 420 volumes and 300 pamphlets.

A considerable number of Maps, Plans, and Charts have been added to the Society's collections by presentations, chiefly from the Ordnance Survey of Great Britain, and from the French Dépôt de la Marine. These amount altogether to 832 sheets, but of them 788 sheets, large and small, are from the Ordnance Survey. Of the remainder, 26 sheets are from the Dépôt de la Marine, 6 from the Geological Survey of Saxony, 6 from that of Sweden, 5 from that of Norway, and 1, a large Geological Map of Canada, from the Canadian Geological Survey.

The Books and Maps above referred to have been received from 154 personal Donors, the Editors or Publishers of 15 Periodicals, and 172 Societies, Surveys, and other Public Bodies, making in all 341 Donors.

By Purchase, on the recommendation of the Standing Library Committee, the Library has received the addition of 32 volumes of Books, and of 55 parts (making about 18 volumes) of various Periodicals, besides 33 parts of certain works published serially. Of the Geological Survey Map of France 9 sheets have been obtained by purchase.

The cost of Books, Periodicals, and Maps purchased during the year 1884 was £83 14*s*. 3*d*., and of Binding £54 9*s*. 8*d*., making a total of £138 3*s*. 11*d*.

Museum.

The Collections in the Museum remain in much the same condition as at the date of the last Report of the Committee.

During the year 1884 several interesting Donations were made to the Museum, the chief among them being a series of fossil Chilostomatous Bryozoa from Muddy Creek, Victoria, Australia, illustrative of Mr. A. W. Waters's papers in the 'Quarterly Journal,' presented by J. Bracebridge Wilson, Esq., of Geelong. The others were :—A specimen of Trowlesworthite, presented by R. N. Worth, Esq., F.G.S.; specimens of "Iron-amianthus," presented by the Rev. J. Magens Mello, F.G.S.; specimens illustrative of his paper on Porthalla Cove, presented by J. H. Collins, Esq., F.G.S.; two slides of Cretaceous Lichenoporidæ, presented by G. R. Vine, Esq.; and casts of Footprints in the Lower New Red Sandstone of Penrith, presented by G. V. Smith, Esq., F.G.S.

COMPARATIVE STATEMENT OF THE NUMBER OF THE SOCIETY AT THE CLOSE OF THE YEARS 1883 AND 1884.

	Dec. 31, 1883.		Dec. 31, 1884.
Compounders	313	......	313
Contributing Fellows	822	......	816
Non-contributing Fellows	222	......	213
	1357		1342
Foreign Members	38	......	40
Foreign Correspondents	39	......	38
	1434		1420

Comparative Statement explanatory of the Alterations in the Number of Fellows, Foreign Members, and Foreign Correspondents at the close of the years 1883 *and* 1884.

Number of Compounders, Contributing and Non-contributing Fellows, December 31, 1883			1357
Add Fellows elected during former year and paid in 1884			9
Add Fellows elected and paid in 1884			34
			1400
Deduct Compounders deceased		6	
Contributing Fellows deceased		19	
Non-contributing Fellows deceased		7	
Contributing Fellows resigned		17	
Non-contributing Fellow resigned		1	
Contributing Fellows removed		8	
		—	58
			1342
Number of Foreign Members, and Foreign Correspondents, December 31, 1883		77	
Deduct Foreign Members deceased	2		
Foreign Correspondents deceased	2		
Foreign Correspondents elected Foreign Members	4		
	—	8	
		69	
Add Foreign Members elected		4	
Foreign Correspondents elected		5	
		—	78
			1420

Deceased Fellows.

Compounders (6).

Adams, G. F., Esq.
Bragge, W., Esq.
Lyon, W., Esq.
Milligan, J., Esq.
Osborne, Lieut.-Col. W.
Wood, S. V., Esq.

Resident and other Contributing Fellows (19).

Beanland, Rev. A.
Browne, W. K., Esq.
Forbes, J. E., Esq.
Godwin-Austen, R. A. C., Esq.
Henty, G. M., Esq.
Herapath, S., Esq.
Hunter, W., Esq.
Hutt, Rev. T. G.
Iselin, J. F., Esq.
Jones, Sir W., Bart.
Murray, Alex., Esq.
Pease, T., Esq.
Richardson, R., Esq.
Silver, Rev. F.
Tomlison, H., Esq.
Tylor, A., Esq.
Vennor, H. G., Esq.
Williams, C. O., Esq.
Williams, J. J., Esq.

Non-contributing Fellows (7).

Buckman, J., Esq.
Colthurst, J., Esq.
Curley, T., Esq.
Jenner, R. F. L., Esq.
Lancaster, J., Esq.
Stokes, Rev. W. H.
Wright, Dr. T.

Foreign Members (2).

Sella, Il Com. Q.
Göppert, Prof. H. R.

Foreign Correspondents.

Hochstetter, Dr. F. von.
Jäger, Dr. G. F.

Fellows Resigned (18).

Cockburn, W., Esq.
Cooke, Maj.-General A. C.
Fox, C. J., Esq.
Gibson, Dr. G. A.
Greaves, Rev. R. W.
Hardwick, P. C., Esq.
Harris, W. H., Esq.
Ladell, H. R., Esq.
Marshall, J., Esq.
Morris, D., Esq.
Neate, P. J., Esq.
Preston, L., Esq.
Rogers, A., Esq.
Ross, Lieut.-Col. W. A.
Sainter, J. D., Esq.
Stair, A., Esq.
Ward, J., Esq.
Willis, J., Esq.

Fellows Removed (8).

Bevan, G. P., Esq.
Byrom, W. A., Esq.
Coates, J., Esq.
Kemshead, Dr. W. B.
Mellor, T. R., Esq.
Parsons, Sergeant W.
Randell, J. E., Esq.
Shaw, Dr. J.

The following Personages were elected from the List of Foreign Correspondents to fill the vacancies in the List of Foreign Members during the year 1884.

Professor G. Capellini of Bologna.
Professor A. L. O. Des Cloizeaux of Paris.
Professor G. Meneghini of Pisa.
Professor J. Szabó of Pesth.

The following Personages were elected Foreign Correspondents during the year 1884.

Dr. Charles Barrois of Lille.
M. Alphonse Briart of Morlanwelz.
Professor Hermann Credner of Leipzig.
Baron C. von Ettingshausen of Gratz.
Dr. E. Mojsisovics von Mojsvár of Vienna.

After the Reports had been read, it was resolved:—

That they be received and entered on the Minutes of the Meeting, and that such parts of them as the Council shall think fit be printed and distributed among the Fellows.

It was afterwards resolved:—

That the thanks of the Society be given to Professor J. Prestwich retiring from the office of Vice-President.

That the thanks of the Society be given to Colonel H. H. Godwin-Austen, Professor T. McKenny Hughes, Professor J. Prestwich, and F. W. Rudler, Esq., retiring from the Council.

After the Balloting-glasses had been duly closed, and the Lists examined by the Scrutineers, the following gentlemen were declared to have been duly elected as the Officers and Council for the ensuing year:—

OFFICERS.

PRESIDENT.

Prof. T. G. Bonney, D.Sc., LL.D., F.R.S.

VICE-PRESIDENTS.

W. Carruthers, Esq., F.R.S.
John Evans, D.C.L., LL.D., F.R.S.
J. W. Hulke, Esq., F.R.S.
J. A. Phillips, Esq., F.R.S.

SECRETARIES.

W. T. Blanford, LL.D., F.R.S.
Prof. J. W. Judd, F.R.S.

FOREIGN SECRETARY.

Warington W. Smyth, Esq., M.A., F.R.S.

TREASURER.

Prof. T. Wiltshire, M.A., F.L.S

COUNCIL.

H. Bauerman, Esq.
W. T. Blanford, LL.D., F.R.S.
Prof. T. G. Bonney, D.Sc., LL.D., F.R.S.
W. Carruthers, Esq., F.R.S.
Prof. W. Boyd Dawkins, M.A., F.R.S.
John Evans, D.C.L., LL.D., F.R.S.
A. Geikie, LL.D., F.R.S.
Henry Hicks, M.D.
Rev. Edwin Hill, M.A.
G. J. Hinde, Ph.D.
John Hopkinson, Esq.
W. H. Hudleston, Esq., M.A., F.R.S.
J. W. Hulke, Esq., F.R.S.
Prof. T. Rupert Jones, F.R.S.
Prof. J. W. Judd, F.R.S.
J. E. Marr, Esq., M.A.
J. A. Phillips, Esq., F.R.S.
W. W. Smyth, Esq., M.A., F.R.S.
J. J. H. Teall, Esq., M.A.
W. Topley, Esq.
Prof. T. Wiltshire, M.A., F.L.S.
Rev. H. H. Winwood, M.A.
H. Woodward, LL.D., F.R.S.

LIST OF
THE FOREIGN MEMBERS
OF THE GEOLOGICAL SOCIETY OF LONDON, IN 1884.

Date of Election.

1827. Dr. H. von Dechen, *Bonn.*
1848. James Hall, Esq., *Albany, State of New York.*
1850. Professor Bernhard Studer, *Berne.*
1851. Professor James D. Dana, *New Haven, Connecticut.*
1851. General G. von Helmersen, *St. Petersburg.*
1853. Count Alexander von Keyserling, *Raykūll, Russia.*
1853. Professor L. G. de Koninck, *Liége.*
1856. Professor Robert Bunsen, For. Mem. R.S., *Heidelberg.*
1857. Professor H. R. Göppert, *Breslau.* (*Deceased.*)
1857. Professor H. B. Geinitz, *Dresden.*
1857. Dr. Hermann Abich, *Vienna.*
1859. Dr. Ferdinand Römer, *Breslau.*
1860. Dr. H. Milne-Edwards, For. Mem. R.S., *Paris.*
1864. M. Jules Desnoyers, *Paris.*
1866. Dr. Joseph Leidy, *Philadelphia.*
1867. Professor A. Daubrée, For. Mem. R.S., *Paris.*
1871. Dr. Franz Ritter von Hauer, *Vienna.*
1874. Professor Alphonse Favre, *Geneva.*
1874. Professor E. Hébert, *Paris.*
1874. Professor Albert Gaudry, *Paris.*
1875. Professor Fridolin Sandberger, *Würzburg.*
1875. Professor Theodor Kjerulf, *Christiania.*
1875. Professor F. August Quenstedt, *Tübingen.*
1876. Professor E. Beyrich, *Berlin.*
1877. Dr. Carl Wilhelm Gümbel, *Munich.*
1877. Dr. Eduard Suess, *Vienna.*
1879. Dr. F. V. Hayden, *Washington.*
1879. Major-General N. von Kokscharow, *St. Petersburg.*
1879. M. Jules Marcou, *Cambridge, U. S.*
1879. Dr. J. J. S. Steenstrup, For. Mem. R.S., *Copenhagen.*
1880. Professor Gustave Dewalque, *Liége.*
1880. Baron Adolf Erik Nordenskiöld, *Stockholm.*
1880. Professor Ferdinand Zirkel, *Leipzig.*
1881. Il Commendatore Quintino Sella, *Rome.* (*Deceased.*)
1882. Professor Sven Lovén, *Stockholm.*
1882. Professor Ludwig Rütimeyer, *Basle.*
1883. Professor J. S. Newberry, *New York.*
1883. Professor Otto Martin Torell, *Stockholm.*
1884. Professor G. Capellini, *Bologna.*
1884. Professor A. L. O. Des Cloizeaux, For. Mem. R.S., *Paris.*
1884. Professor G. Meneghini, *Pisa.*
1884. Professor J. Szabó, *Pesth.*

LIST OF
THE FOREIGN CORRESPONDENTS
OF THE GEOLOGICAL SOCIETY OF LONDON, IN 1884.

Date of Election.

1863. Dr. G. F. Jäger, *Stuttgart*. (*Deceased.*)
1863. Count A. G. Marschall, *Vienna*.
1863. Professor Giuseppe Ponzi, *Rome*.
1863. Dr. F. Senft, *Eisenach*.
1864. Dr. Charles Martins, *Montpellier*.
1866. Professor J. P. Lesley, *Philadelphia*.
1866. Professor Victor Raulin, *Bordeaux*.
1866. Baron Achille de Zigno, *Padua*.
1872. Herr Dionys Stur, *Vienna*.
1872. Professor J. D. Whitney, *Cambridge, U. S.*
1874. Professor Igino Cocchi, *Florence*.
1874. M. Gustave H. Cotteau, *Auxerre*.
1874. Professor G. Seguenza, *Messina*.
1874. Dr. T. C. Winkler, *Haarlem*.
1875. Professor Gustav Tschermak, *Vienna*.
1876. Professor Jules Gosselet, *Lille*.
1877. Professor George J. Brush, *New Haven*.
1877. Professor E. Renevier, *Lausanne*.
1877. Count Gaston de Saporta, *Aix-en-Provence*.
1879. Professor Pierre J. van Beneden, For.Mem.R.S., *Louvain*.
1879. M. Édouard Dupont, *Brussels*.
1879. Professor Guglielmo Guiscardi, *Naples*.
1879. Professor Gerhard Vom Rath, *Bonn*.
1879. Dr. Émile Sauvage, *Paris*.
1880. Professor Luigi Bellardi, *Turin*.
1880. Dr. Ferdinand von Hochstetter, *Vienna*. (*Deceased.*)
1880. Professor Leo Lesquereux, *Columbus*.
1880. Dr. Melchior Neumayr, *Vienna*.
1880. M. Alphonse Renard, *Brussels*.
1881. Professor E. D. Cope, *Philadelphia*.
1882. Professor Louis Lartet, *Toulouse*.
1882. Professor Alphonse Milne-Edwards, *Paris*.
1883. M. François Leopold Cornet, *Mons*.
1883. Baron Ferdinand von Richthofen, *Leipzig*.
1883. Professor Karl Alfred Zittel, *Munich*.
1884. Dr. Charles Barrois, *Lille*.
1884. M. Alphonse Briart, *Morlanwelz*.
1884. Professor Hermann Credner, *Leipzig*.
1884. Baron C. von Ettingshausen, *Gratz*.
1884. Dr. E. Mojsisovics von Mojsvár, *Vienna*.

AWARDS OF THE WOLLASTON MEDAL

UNDER THE CONDITIONS OF THE "DONATION FUND"

ESTABLISHED BY

WILLIAM HYDE WOLLASTON, M.D., F.R.S., F.G.S., &c.

"To promote researches concerning the mineral structure of the earth, and to enable the Council of the Geological Society to reward those individuals of any country by whom such researches may hereafter be made,"—"such individual not being a Member of the Council."

1831. Mr. William Smith.
1835. Dr. G. A. Mantell.
1836. M. Louis Agassiz.
1837. Capt. T. P. Cautley. / Dr. H. Falconer.
1838. Sir Richard Owen.
1839. Professor C. G. Ehrenberg.
1840. Professor A. H. Dumont.
1841. M. Adolphe T. Brongniart.
1842. Baron L. von Buch.
1843. M. Elie de Beaumont. / M. P. A. Dufrénoy.
1844. Rev. W. D. Conybeare.
1845. Professor John Phillips.
1846. Mr. William Lonsdale.
1847. Dr. Ami Boué.
1848. Rev. Dr. W. Buckland.
1849. Professor Joseph Prestwich.
1850. Mr. William Hopkins.
1851. Rev. Prof. A. Sedgwick.
1852. Dr. W. H. Fitton.
1853. M. le Vicomte A. d'Archiac. / M. E. de Verneuil.
1854. Sir Richard Griffith.
1855. Sir H. T. De la Beche.
1856. Sir W. E. Logan.
1857. M. Joachim Barrande.
1858. Herr Hermann von Meyer. / Mr. James Hall.
1859. Mr. Charles Darwin.
1860. Mr. Searles V. Wood.
1861. Professor Dr. H. G. Bronn.
1862. Mr. R. A. C. Godwin-Austen.
1863. Professor Gustav Bischof.
1864. Sir R. I. Murchison.
1865. Dr. Thomas Davidson.
1866. Sir Charles Lyell.
1867. Mr. G. Poulett Scrope.
1868. Professor Carl F. Naumann.
1869. Dr. H. C. Sorby.
1870. Professor G. P. Deshayes.
1871. Sir A. C. Ramsay.
1872. Professor J. D. Dana.
1873. Sir P. de M. Grey-Egerton.
1874. Professor Oswald Heer.
1875. Professor L. G. de Koninck.
1876. Professor T. H. Huxley.
1877. Mr. Robert Mallet.
1878. Dr. Thomas Wright.
1879. Professor Bernhard Studer.
1880. Professor Auguste Daubrée.
1881. Professor P. Martin Duncan.
1882. Dr. Franz Ritter von Hauer.
1883. Mr. W. T. Blanford.
1884. Professor Albert Gaudry.
1885. Mr. George Busk.

AWARDS

OF THE

BALANCE OF THE PROCEEDS OF THE WOLLASTON "DONATION-FUND."

1831. Mr. William Smith.
1833. Mr. William Lonsdale.
1834. M. Louis Agassiz.
1835. Dr. G. A. Mantell.
1836. Professor G. P. Deshayes.
1838. Sir Richard Owen.
1839. Professor C. G. Ehrenberg.
1840. Mr. J. De Carle Sowerby.
1841. Professor Edward Forbes.
1842. Professor John Morris.
1843. Professor John Morris.
1844. Mr. William Lonsdale.
1845. Mr. Geddes Bain.
1846. Mr. William Lonsdale.
1847. M. Alcide d'Orbigny.
1848. { Cape-of-Good-Hope Fossils. / M. Alcide d'Orbigny.
1849. Mr. William Lonsdale.
1850. Professor John Morris.
1851. M. Joachim Barrande.
1852. Professor John Morris.
1853. Professor L. G. de Koninck.
1854. Dr. S. P. Woodward.
1855. Drs. G. and F. Sandberger.
1856. Professor G. P. Deshayes.
1857. Dr. S. P. Woodward.
1858. Mr. James Hall.
1859. Mr. Charles Peach.
1860. { Professor T. Rupert Jones. / Mr. W. K. Parker.
1861. Professor A. Daubrée.
1862. Professor Oswald Heer.
1863. Professor Ferdinand Senft.
1864. Professor G. P. Deshayes.
1865. Mr. J. W. Salter.
1866. Dr. Henry Woodward.
1867. Mr. W. H. Baily.
1868. M. J. Bosquet.
1869. Mr. W. Carruthers.
1870. M. Marie Rouault.
1871. Mr. R. Etheridge.
1872. Dr. James Croll.
1873. Professor J. W. Judd.
1874. Dr. Henri Nyst.
1875. Mr. L. C. Miall.
1876. Professor Giuseppe Seguenza.
1877. Mr. R. Etheridge, Jun.
1878. Professor W. J. Sollas.
1879. Mr. S. Allport.
1880. Mr. Thomas Davies.
1881. Dr. R. H. Traquair.
1882. Dr. G. J. Hinde.
1883. Mr. John Milne.
1884. Mr. E. Tulley Newton.
1885. Dr. C. Callaway.

AWARDS OF THE MURCHISON MEDAL

AND OF THE

PROCEEDS OF "THE MURCHISON GEOLOGICAL FUND,"

ESTABLISHED UNDER THE WILL OF THE LATE

SIR RODERICK IMPEY MURCHISON, BART., F.R.S., F.G.S.

"To be applied in every consecutive year in such manner as the Council of the Society may deem most useful in advancing geological science, whether by granting sums of money to travellers in pursuit of knowledge, to authors of memoirs, or to persons actually employed in any inquiries bearing upon the science of geology, or in rewarding any

such travellers, authors, or other persons, and the Medal to be given to some person to whom such Council shall grant any sum of money or recompense in respect of geological science."

1873. Mr. William Davies. *Medal.*
1873. Professor Oswald Heer.
1874. Dr. J. J. Bigsby. *Medal.*
1874. Mr. Alfred Bell.
1874. Professor Ralph Tate.
1875. Mr. W. J. Henwood. *Medal.*
1875. Professor H. G. Seeley.
1876. Mr. A. R. C. Selwyn. *Medal.*
1876. Dr. James Croll.
1877. Rev. W. B. Clarke. *Medal.*
1877. Professor J. F. Blake.
1878. Dr. H. B. Geinitz. *Medal.*
1878. Professor C. Lapworth.
1879. Professor F. M'Coy. *Medal.*
1879. Mr. J. W. Kirkby.
1880. Mr. R. Etheridge. *Medal.*
1881. Professor A. Geikie. *Medal.*
1881. Mr. F. Rutley.
1882. Professor J. Gosselet. *Medal.*
1882. Professor T. Rupert Jones.
1883. Professor H. R. Göppert. *Medal.*
1883. Mr. John Young.
1884. Dr. H. Woodward. *Medal.*
1884. Mr. Martin Simpson.
1885. Professor F. Römer. *Medal.*
1885. Mr. H. B. Woodward.

AWARDS OF THE LYELL MEDAL

AND OF THE

PROCEEDS OF THE "LYELL GEOLOGICAL FUND,"

ESTABLISHED UNDER THE WILL AND CODICIL OF THE LATE SIR CHARLES LYELL, BART., F.R.S., F.G.S.

The Medal "to be given annually" (or from time to time) "as a mark of honorary distinction as an expression on the part of the governing body of the Society that the Medallist has deserved well of the Science,"—"not less than one third of the annual interest [of the fund] to accompany the Medal, the remaining interest to be given in one or more portions at the discretion of the Council for the encouragement of Geology or of any of the allied sciences by which they shall consider Geology to have been most materially advanced."

1876. Professor John Morris. *Medal.*
1877. Dr. James Hector. *Medal.*
1877. Mr. W. Pengelly.
1878. Mr. G. Busk. *Medal.*
1878. Dr. W. Waagen.
1879. Professor Edmond Hébert. *Medal.*
1879. Professor H. A. Nicholson.
1879. Dr. Henry Woodward.
1880. Mr. John Evans. *Medal.*
1880. Professor F. Quenstedt.
1881. Sir J. W. Dawson. *Medal.*
1881. Dr. Anton Fritsch.
1881. Mr. G. R. Vine.
1882. Dr. J. Lycett. *Medal.*
1882. Rev. Norman Glass.
1882. Professor C. Lapworth.
1883. Dr. W. B. Carpenter. *Medal.*
1883. Mr. P. H. Carpenter.
1883. M. E. Rigaux.
1884. Dr. Joseph Leidy. *Medal.*
1884. Professor Charles Lapworth.
1885. Professor H. G. Seeley. *Medal.*
1885. Mr. A. J. Jukes-Browne.

AWARDS OF THE BIGSBY MEDAL,

FOUNDED BY

DR. J. J. BIGSBY, F.R.S., F.G.S.

To be awarded biennially "as an acknowledgment of eminent services in any department of Geology, irrespective of the receiver's country; but he must not be older than 45 years at his last birthday, thus probably not too old for further work, and not too young to have done much."

1877. Professor O. C. Marsh.
1879. Professor E. D. Cope.
1881. Dr. C. Barrois.
1883. Dr. Henry Hicks.
1885. M. Alphonse Renard.

AWARDS OF THE PROCEEDS OF THE BARLOW-JAMESON FUND,

ESTABLISHED UNDER THE WILL OF THE LATE

DR. H. C. BARLOW, F.G.S.

"The perpetual interest to be applied every two or three years, as may be approved by the Council, to or for the advancement of Geological Science."

1880. Purchase of microscope.
1881. Purchase of microscope lamps.
1882. Baron C. von Ettingshausen.
1884. Dr. James Croll.
1884. Professor Leo Lesquereux.

ESTIMATES *for*

INCOME EXPECTED.

	£	s.	d.	£	s.	d.
Due for Subscriptions for Quarterly Journal ..	2	0	0			
Due for Arrears of Annual Contributions	160	0	0			
Due for Arrears of Admission-fees	81	16	0			
				243	16	0
Estimated Ordinary Income for 1885:—						
Annual Contributions from Resident Fellows, and Non-residents 1859 to 1861				1440	0	0
Admission-fees				252	0	0
Compositions				168	0	0
Annual Contributions in advance				21	0	0
Dividends on Consols and Reduced 3 per Cents.				230	0	0
Advertisements in Quarterly Journal..................				5	10	0
Sale of Transactions, Library-catalogue, Ormerod's Index, Hochstetter's New Zealand, and List of Fellows	6	0	0			
Sale of Quarterly Journal, including Longman's account	200	0	0			
Sale of Geological Map, including Stanford's account	15	0	0			
				221	0	0
				£2581	6	0

THOMAS WILTSHIRE, TREAS.

11 *Feb.* 1885.

the Year 1885.

EXPENDITURE ESTIMATED.

	£	s.	d.	£	s.	d.
House Expenditure:						
Taxes and Insurance	34	10	0			
Gas	22	0	0			
Fuel	30	0	0			
Furniture and Repairs	20	0	0			
House-repairs and Maintenance	15	0	0			
Annual Cleaning	20	0	0			
Washing and Sundries	32	0	0			
Tea at Meetings	16	0	0			
				189	10	0
Salaries and Wages:						
Assistant Secretary	350	0	0			
Clerk	160	0	0			
Assistant in Library and Museum	130	0	0			
House Steward	105	0	0			
Housemaid	40	0	0			
Errand Boy	46	16	0			
Charwoman and Occasional Assistance	30	0	0			
Attendants at Meetings	8	0	0			
Accountants	10	10	0			
				880	6	0
Official Expenditure:						
Stationery	25	0	0			
Miscellaneous Printing	22	0	0			
Postages and other Expenses	65	0	0			
				112	0	0
Library				150	0	0
Soirée (half cost)				34	0	0
Publications:						
Geological Map	20	0	0			
Quarterly Journal	950	0	0			
,, ,, Commission, Postage, and Addressing	100	0	0			
List of Fellows	34	0	0			
Abstracts, including Postage	110	0	0			
				1214	0	0
Balance in favour of the Society				1	10	0
				£2581	6	0

Income and Expenditure during the

RECEIPTS.

	£	s.	d.	£	s.	d.
Balance in Bankers' hands, 1 January 1884	346	0	1			
Balance in Clerk's hands, 1 January 1884	16	3	5			
				362	3	6
Compositions				168	0	0
Arrears of Admission-fees	56	14	0			
Admission-fees, 1884	214	4	0			
				270	18	0
Arrears of Annual Contributions				157	7	6
Annual Contributions for 1884, viz.:						
Resident Fellows	1415	8	0			
Non-Resident Fellows	18	18	0			
				1434	6	0
Annual Contributions in advance				35	14	0
Dividends on Consols	204	3	1			
,, Reduced 3 per Cents.	30	8	10			
				234	11	11
Taylor & Francis: Advertisements in Journal, Vol. 39				5	10	9
Publications:						
Sale of Journal, Vols. 1–39	113	16	0			
,, Vol. 40 *	80	8	9			
Sale of Library Catalogue	2	7	0			
Sale of Geological Map	20	7	8			
Sale of Ormerod's Index	1	15	1			
Sale of Hochstetter's New Zealand	0	12	0			
Sale of Transactions	1	4	0			
Sale of List of Fellows	0	3	0			
				220	13	6
*Due from Messrs. Longman, in addition to the above, on Journal, Vol. 40, &c.	66	9	9			
Due from Stanford on account of Geological Map	3	1	1			
	69	10	10			
				£2889	5	2

We have compared this statement with the Books and Accounts presented to us, and find them to agree.

(Signed) W. H. HUDLESTON, J. ARTHUR PHILLIPS, } *Auditors.*

9 *Feb.* 1885.

Year ending 31 *December*, 1884.

EXPENDITURE.

	£	s.	d.	£	s.	d.
House Expenditure:						
Taxes	19	2	6			
Fire-insurance	12	0	0			
Gas	20	19	5			
Fuel	28	17	0			
Furniture and Repairs	11	2	9			
House-repairs	12	11	4			
Annual Cleaning	19	13	5			
Washing and Sundries	31	15	1			
Tea at Meetings	16	0	0			
				172	1	6
Salaries and Wages:						
Assistant Secretary	350	0	0			
Clerk	160	0	0			
Assistant in Library and Museum	130	0	0			
House Steward	105	0	0			
Housemaid	40	0	0			
Errand Boy	44	16	0			
Charwoman	28	17	6			
Attendants at Meetings	8	0	0			
Accountants	10	10	0			
				877	3	6
Official Expenditure:						
Stationery	21	15	1			
Miscellaneous Printing	21	13	3			
Postages and other Expenses	75	8	9			
				118	17	1
Library				138	3	11
Publications:						
Geological Map	24	10	11			
Journal, Vols. 1–39	12	13	1			
,, Vol. 40 … 1106 5 4						
,, ,, Commission, Postage, and Addressing . 105 2 0						
	1211	7	4			
List of Fellows	33	12	9			
Abstracts, including Postage	111	7	5			
				1393	11	6
Investment in £99 0*s.* 2*d.* Consols				100	0	0
Balance in Bankers' hands, 31 Dec. 1884	73	4	9			
Balance in Clerk's hands, 31 Dec. 1884	16	2	11			
				89	7	8
				£2889	5	2

"Wollaston Donation Fund." Trust Account.

Receipts.	£	s.	d.	Payments.	£	s.	d.
Balance at Bankers', 1 January 1884	31	14	11	Cost of striking Gold Medal awarded to Professor Albert Gaudry	10	10	0
Dividends on the Fund invested in Reduced 3 per Cents.	31	16	10	Award to Mr. E. Tulley Newton	18	1	11
				Part cost of New Dies (fourth instalment)	3	3	0
				Balance at Bankers', 31 December 1884	31	16	10
	£63	11	9		£63	11	9

"Murchison Geological Fund." Trust Account.

Receipts.	£	s.	d.	Payments.	£	s.	d.
Balance at Bankers', 1 January 1884	19	10	5	Award to Dr. Henry Woodward, with Medal	10	10	0
Dividends on the Fund invested in London and North-Western Railway 4 per cent. Debenture Stock	39	3	4	" Mr. M. Simpson	28	12	1
				Balance at Bankers', 31 December 1884	19	11	8
	£58	13	9		£58	13	9

"Lyell Geological Fund." Trust Account.

Receipts.	£	s.	d.	Payments.	£	s.	d.
Balance at Bankers', 1 January 1884	51	11	3	Award to Dr. Joseph Leidy, with Medal	25	0	0
Dividends on the Fund invested in Metropolitan $3\frac{1}{2}$ per cent. Stock	68	18	0	" Professor C. Lapworth	43	15	9
				Balance at Bankers', 31 December 1884	51	13	6
	£120	9	3		£120	9	3

"Barlow-Jameson Fund." Trust Account.

Receipts.	£	s.	d.	Payments.	£	s.	d.
Balance at Bankers', 1 January 1884	37	2	4	Award to Dr. James Croll	20	0	0
Dividends on the Fund invested in Consols	14	13	8	" Professor Leo Lesquereux	20	0	0
				Balance at Bankers', 31 December 1884	11	16	0
	£51	16	0		£51	16	0

"Bigsby Fund." Trust Account.

Receipts.	£	s.	d.	Payments.	£	s.	d.
Balance at Bankers', 1 January 1884	6	2	7	Balance at Bankers', 31 December 1884	12	5	7
Dividends on the Fund invested in New 3 per Cents	6	3	0				
	£12	5	7		£12	5	7

Valuation of the Society's Property; 31 December, 1884.

Property.	£	s.	d.	£	s.	d.	Debts.	£	s.	d.
Due from Longman & Co., on account of Journal, vol. xl. &c.				66	9	9	Balance in favour of the Society	8397	16	4
Due from Stanford on account of Map				3	1	1				
Due from Subscribers to Journal (considered good)				2	0	0				
Balance in Bankers' hands, 31 Dec. 1884				73	4	9				
Balance in Clerk's hands, 31 Dec. 1884				16	2	11				
Funded Property:—										
Consols, at $99\frac{1}{2}$	6999	7	4	6964	0	0				
Reduced 3 per Cents. at $99\frac{1}{2}$	1036	5	5	1031	1	10				
Arrears of Admission-fees (considered good)				81	16	0				
Arrears of Annual Contributions (considered good)				160	0	0				
				£8397	16	4		£8397	16	4

[*N.B. The above does not include the value of the Collections, Library, Furniture, and stock of unsold Publications.*]

THOMAS WILTSHIRE, *Treas.*

11 *Feb.* 1885.

Award of the Wollaston Medal.

In handing the Wollaston Gold Medal to Dr. W. T. Blanford, F.R.S., for transmission to Mr. George Busk, F.R.S., F.G.S., the President addressed him as follows :—

Dr. Blanford,—

The Council of the Geological Society has awarded to Mr. George Busk the Wollaston Medal in recognition of the value of his researches in more than one branch of Palæontology. Polyzoa, not only fossil but also recent, he has made peculiarly his own; and his numerous separate papers, his British Museum Catalogue, and his memoir on the Polyzoa of the Crag, have entitled him to the lasting gratitude of workers at this class of the Molluscoida. But, perhaps as a relief to the study of these minute invertebrates, he has occupied himself, not less successfully, with the larger vertebrata, so that to him we are indebted for much information on the fauna of Post-tertiary deposits, especially from the caves of Malta and of Brixham. Permit me, in handing you this Medal for transmission to Mr. Busk, to express my pleasure at having such a duty to discharge, and my earnest hope, in which I am sure all present will share, that restored health may enable him to continue his work in the cause of our science.

Dr. Blanford, in reply, expressed his gratification at being selected as the medium for transmitting the Wollaston Medal to Mr. Busk, whose compulsory absence he nevertheless greatly regretted, and from whom he read the following letter :—

"32 Harley Street, W.
"Feb. 19, 1885.

"Dear Mr. President,—

"As, much to my regret and disappointment, I find myself unable to attend the Annual Meeting, I must trespass upon your kindness to express my warmest thanks and best acknowledgments for the honour you and the Council have conferred upon me in the award of the oldest of the Society's Medals, and whose recipients form such a long and distinguished roll, to which any one may indeed be proud to see his name added.

"The honour, also, in my eyes, is doubly gratifying as being the second testimonial of the same kind, and showing the favourable estimation in which my few labours have been held by the Geological Society of London, whose continued prosperity and usefulness will always be an object of my warmest wishes.

"Believe me,
Yours very sincerely,
Geo. Busk."

Prof. T. G. Bonney, F.R.S.

Award of the Wollaston Donation Fund.

The President then presented the Balance of the Proceeds of the Wollaston Donation Fund to Dr. Charles Callaway, F.G.S., and addressed him as follows:—

Dr. Charles Callaway,—

The Council of the Geological Society has awarded to you the balance of the proceeds of the Wollaston Donation Fund, in recognition of the value of your researches among the older British rocks. By your identification of Upper Cambrian rocks in Shropshire you have placed beyond question the antiquity of the Rhyolitic group of the Wrekin, our knowledge of which and of yet older rocks in that district you have greatly augmented. Your contributions also to the geology of Anglesey and towards unravelling the stratigraphy of the Scotch Highlands have been of great value, and we look forward to the results of further researches, in aid of which I have great pleasure in placing in your hands the amount of the award. That you receive it from a fellow-labourer will, I hope, make it not the less welcome.

Dr. Callaway, in reply, said:—

Mr. President,—

I highly value the honour which the Council has seen fit to confer upon me, and I shall not readily forget the kind words with which you have accompanied the award. We are told that the reward of virtue is not bread; but bread is a sustainer of virtue: and in like manner, though geology is its own reward, the geologist is conscious of discouragement if the appreciation of his fellow-workers is withheld. I therefore regard this award as an effective stimulus to future exertion. It is a great pleasure to me to receive it at the hands of one who has so often been a kindly helper in working out difficult problems in lithology.

Award of the Murchison Medal.

The President then handed the Murchison Medal to Dr. Henry Woodward, F.R.S., for transmission to Dr. Ferdinand Römer, F.M.G.S., of Breslau, and addressed him as follows:—

Dr. Woodward,—

The Council has awarded to Dr. Ferdinand Römer the Murchison Medal and a sum of Ten Guineas from the Donation Fund. His life-long and unwearied labours in the service of our science have long since made his name familiar to his fellow-workers. When I state that the Royal Society Catalogue, published now more than

eleven years since, records the titles of 122 separate memoirs written by him, when I mention his other important works, such as that on the Chalk Formation of Texas, on the Silurian Fauna of Tennessee, on the Geology of Upper Silesia, and the 'Lethæa Geognostica,' I have said enough to prove that this memorial of an illustrious geologist could not well have been bestowed on a more illustrious recipient. In transmitting it to Dr. Römer, be so kind as to express our regret that distance and the season of the year have deprived us of the pleasure of his presence on this occasion.

Dr. Woodward expressed his pleasure at being deputed to receive this Medal for Dr. Ferdinand Römer, from whom he had received the following letter:—

"Mr. President,—

"I am deeply sensible of the honour which you and the Council of the Geological Society have conferred upon me in presenting me with the Murchison Medal.

"I very much regret my inability to be present in order to receive this valuable mark of appreciation from your hands, and to express personally to you my sincere thanks for this high mark of recognition which the Society has bestowed on me.

"It is particularly gratifying to me that it is *the Murchison Medal* which you have been pleased to confer upon me, because the greater part of my scientific work has been directed to the study of those ancient rocks, the natural order of which was first recognized by the comprehensive genius of its founder, Sir Roderick Murchison.

"Ferd. Römer."

Award of the Murchison Geological Fund.

In presenting the balance of the proceeds of the Murchison Geological Fund to Mr. Horace B. Woodward, F.G.S., the President addressed him as follows:—

Mr. Horace B. Woodward,—

The balance of the proceeds of the Murchison Donation Fund has been awarded to you in recognition of the good service which you have already rendered to geology, especially by your work among the later deposits of the eastern counties, and to aid you in further researches. But the excellent papers which you have written, in addition to the work done by you as a member of the Geological Survey, do not constitute your only claim to our recognition. You have made use of the opportunity of your official position to promote a love of science among those who live in our eastern counties, and we are indebted to you for that admirable volume the 'Geology of England and Wales,' which, though in one sense a compilation, is such a one as only a skilled geologist could produce.

Mr. Woodward, in reply, said:—

Mr. President,—

I am highly honoured by this award of the Council which you have now placed in my hands. A little more than twenty-one years ago I commenced geological life in the service of this Society, as Assistant in the Library and Museum at Somerset House; and I feel much indebted to that period for acquaintance with many geologists, who, for the sake of my father, extended the hand of friendship to me; and I am likewise indebted to the duties I had then to perform for a knowledge (and I may say a love) of books, which perhaps influenced the production of that volume about which you have spoken so kindly.

While labour is in most cases its own reward, it is a great satisfaction and a great encouragement to be told that one's work is useful by those who are best qualified to judge.

Award of the Lyell Medal.

The President next presented the Lyell Medal to Professor H. G. Seeley, F.R.S., F.G.S., and addressed him as follows:—

Professor Seeley,—

The Council has awarded to you the Lyell Medal and a grant of £40 in recognition of your investigations into the anatomy and classification of the Fossil Reptilia, especially the Dinosauria. Not that you have limited yourself to this field of research; your papers on *Emys* and *Psephophorus*, on *Megalornis* and British Fossil Cretaceous Birds, on *Zeuglodon*, and on remains of Mammalia from Stonesfield, prove your extensive knowledge of vertebrate palæontology, as your proficiency in invertebrate is evidenced by your earlier work, both stratigraphical and directly palæontological. Furthermore, your excellent edition of the first volume of Phillips's 'Manual of Geology' indicates an exceptional familiarity with the literature of our science. Since our acquaintance first began, some twenty years since, at Cambridge, we have both had our disappointments and our successes; you, undiscouraged by the one, unelated by the other, have pushed on to your present high position in science, making no enemies, winning many friends. I trust that your future career may be even more prosperous than your past, and that this Medal may be an augury of many good gifts of fortune. You will, I know, believe me when I say that I feel an exceptional pleasure in being commissioned to place in your hands this Medal, commemorative of the great geologist whose philosophic spirit you so well appreciate, and whose memory, I know, you so greatly revere.

Professor SEELEY, in reply, said:—

Mr. PRESIDENT,—

No words of mine could adequately reflect my sense of the kind words and kind feelings to which you have given expression. I must, however, say that the honour of this award is one for which I am sincerely grateful. It is needless now to say anything in admiration of Lyell, but I may give utterance to a sense of personal obligation by saying that he has always seemed to me the greatest teacher of our science. In receiving the Medal, however, which is associated with his name, I cannot but be conscious how far short what I have done has fallen of my efforts and aspirations, and that more work than I can hope to do should have been before you in justification. With regard to the new edition of Phillips's Geology, I would say that that work, founded on the necessities of my own teaching, was undertaken to do honour to the memory of my old friend, Professor John Phillips; but it would have been more imperfectly done without the important help which I found in your own writings. I shall find in this award a stimulus to future work, which I hope may give results more worthy of recognition than the work to which you have referred.

AWARD OF THE LYELL GEOLOGICAL FUND.

The PRESIDENT then handed the Balance of the proceeds of the Lyell Geological Fund to Mr. J. J. H. TEALL, F.G.S., for transmission to Mr. A. J. JUKES-BROWNE, F.G.S., and addressed him as follows:—

Mr. TEALL,—

The balance of the Lyell Donation Fund has been awarded to Mr. A. J. Jukes-Browne in recognition of the excellent work that he has done on the Cretaceous formation and on Glacial geology, and to aid him in further researches. His papers on the Cambridge Greensand cleared up many difficulties connected with that interesting formation; and in his Sedgwick prize essay on the Post-tertiary deposits of Cambridgeshire he commenced those investigations which have since brought us more than one valuable contribution on glacial and later deposits. You can tell him that his old college tutor feels a little pardonable pride and much real pleasure in being the instrument of placing this award in your hands for transmission to him.

Mr. TEALL, in reply, expressed his regret that Mr. JUKES-BROWNE was prevented by domestic anxieties from being present, and read an extract from a letter received from him. In this Mr. JUKES-BROWNE said:—

"That my labours in the field of geology should have been thought worthy of such recognition is most gratifying and encouraging, and I am especially pleased that the award should come from the Lyell Donation Fund; for among all the departed masters of our science there is no one for whom I feel greater respect than for Sir Charles Lyell, or whose mental attitude I more desire to imitate. To be entered therefore on the roll of those who are deemed worthy of receiving the award instituted by Sir Charles Lyell will always be a source of extreme pleasure.

"I need hardly assure the Council and Fellows of the Society that such strength and powers as I possess will be spent in the service of geological science, because that must be so as long as I am connected with the Geological Survey; but this mark of their approbation will stimulate me in the performance of such extra-official work as I am able to accomplish, and I only wish that my health would allow me to do more."

Award of the Bigsby Gold Medal.

In presenting the Bigsby Gold Medal to Professor Renard, of Brussels, the President addressed him as follows:—

Professor Renard,—

When to a familiarity with geology in the field and a love of nature are united the skill of a finished chemist and the experience of a practised worker with the microscope, the results cannot fail to be of the utmost importance to our science. These qualifications, rarely united in any one man, are in yourself combined with an untiring industry and a love of science for its own sake. Thus we are indebted to you for many important contributions to our knowledge in geology. Your early memoir "Sur les Roches Plutoniennes de la Belgique et de l'Ardenne Française," written in conjunction with M. de la Vallée Poussin, will long be classic; your papers on various subjects connected with the Carboniferous Limestone, on the coticule, the phyllites, and other altered rocks of Belgium, and on the deep-sea deposits are too well known to need more than mention, and in recognition of these the Council has awarded you the Bigsby Medal.

In placing it in your hands may I be allowed to express for myself and others the hope that it will be always a pleasant *souvenir* of your many friends on this side of the Channel, some of whom, myself included, will not soon forget the pleasant and, to us, most profitable days spent under your guidance in geological studies by the limestone cliffs of the winding Meuse and the wooded crags of the Ardennes.

Professor RENARD, in reply, said:—

Mr. PRESIDENT and GENTLEMEN,—

In rising to express my thanks to you, I labour under a great disadvantage; it would have greatly conduced to my comfort to speak in my own language, but the magnitude of the honour you have conferred upon me makes me feel that I must at all events attempt to address you in your tongue.

To hold the Medal which you have awarded to me is no common distinction. I cannot but feel that you are rating my merits more highly than they deserve. Though not an Englishman, I never feel myself a stranger in your country. I have visited it so often, and had so much friendly intercourse with your scientific men, that I am not altogether without misgiving that your Council may, unconsciously to themselves, have supplemented my deficiencies as a geologist by their personal friendliness towards myself. The particular line of study to which I have devoted myself is essentially English. Your countryman, Sorby, was the pioneer of microscopic lithology, and I have only followed the track which he was the first to open up.

In conclusion, allow me to say that though sensible of my own deficiencies, I am confident that your good opinion will stimulate me to fresh exertions. I shall pursue my scientific work with renewed energy, and it will be my constant endeavour to show you that your confidence was not altogether misplaced, and make myself in the future worthy of the great honour you have conferred upon me.

THE ANNIVERSARY ADDRESS OF THE PRESIDENT.

PROF. T. G. BONNEY, D.Sc., LL.D., F.R.S.

GENTLEMEN,

In referring last year to the muster-roll of death, your President remarked that it contained the name of only one Fellow who had been a contributor to our publications. Unhappily I am unable to repeat the remark. Earnest workers and valued friends during my year of office have been falling "thick as autumn leaves in Valombrosa." It is now my melancholy duty to pay to these the last tribute of respect, and dwell for a brief space on their memory.

In ROBERT ALFRED CLOYNE GODWIN-AUSTEN we have lost not only a geologist of extensive knowledge and of an exceptionally philosophic mind, but also one of the links which united us with what we may almost call the "heroic age" of British Geology. He was born at Shalford House, near Guildford, on March 17, 1808, being the eldest son of the late Sir H. E. Austen. Educated first at Midhurst School, he afterwards spent some time at a military college in France. Thence he proceeded to Oxford, where he graduated and was elected a Fellow of Oriel College. Coming thus under the influence of Buckland, he was secured for geology, and was elected a Fellow of this Society in the year 1830. Three years afterwards he married the only daughter and heiress of the late General Sir H. T. Godwin, K.C.B., and on the death of that officer in 1854, prefixed the name of Godwin to that of Austen. Devonshire was the scene of his earlier geological labours; for not long after his election to this Society he fixed his residence at Ogwell House, near Newton Abbot. His first contribution to our publications was made in 1834, and for the next six years Devonshire formed the chief subject of his writings. The first paper relating to the south-east of England appears in the 'Proceedings' for 1853, and after his removal from Devonshire to Chilworth Manor, near Guildford, the Cretaceous and Tertiary deposits, together with physical questions relating to the geology of the Channel and its vicinity received a large share of his attention, although Devonshire was not forgotten.

Mr. Godwin-Austen was elected a Fellow of the Royal Society in 1849. He received various distinctions from Foreign Societies; and the Wollaston Medal was awarded to him in 1862. Mr. Godwin-Austen was also an energetic Member of the British Association, and twice, at Norwich and at Brighton, presided over the Geological Section. For the greater part of his life his connexion with the Geological Society was of the closest kind; a large number of his papers were contributed to our publications; he served as one of the Secretaries; subsequently he was in office as Foreign Secretary and as a Vice-President; and it is well known that, had he been willing, the

Society would have gladly elected him President. He finally quitted the Council in 1876, about which time his health became much impaired, and he was afterwards unable to take any active part in our meetings or in our work. After a lingering illness, he expired on the 25th November last, to the regret of all who enjoyed the privilege of his friendship. The name, however, of Godwin-Austen will, fortunately, not disappear from our lists, for the personal influence and the scientific ability of the father have been transmitted to his son, our friend Colonel Godwin-Austen.

Of the contributions to science of the late Mr. Godwin-Austen it is impossible, within the brief space allotted to these notices, to give any adequate idea. A list of 39 papers is appended to a biography by Mr. H. B. Woodward (to which I am much indebted), published in the 'Geological Magazine' for January last. In addition to these, he edited the Memoir on the Fluvio-marine Tertiaries of the Isle of Wight, left in manuscript by its lamented author, the late Professor E. Forbes, and completed the 'Natural History of the European Seas,' commenced by the same author. The whole book, after p. 126, is the work of Mr. Godwin-Austen. He also made important contributions to the new edition of the 'Greenough Geological Map,' published in 1865.

His papers on the classification and correlation of the rocks of Devonshire will ever be classic in the history of that most difficult region. Mr. Godwin-Austen, as is well known, objected to the distinction of the fossiliferous rocks beneath the Culm-measures by the title of Devonian, and to the equivalence assumed between these and the Old Red Sandstone further north, considering the latter to be more nearly connected with the base of the Carboniferous series, and the former as the representative in time of the Upper Silurian, the differences of the fauna being regarded as due to the two being deposited in different and separated marine areas. Although the general tendency of subsequent research has been unfavourable to the view upheld by Mr. Godwin-Austen, still it is one which cannot wholly be neglected, and modifications in the direction of it seem likely to be made in the generally received theory. But on whatever question Mr. Godwin-Austen wrote, whether on nodules in the Faringdon Sands or on boulders in the Chalk, whether on superficial or subterranean geology, whether on the physical features of the present or of past geological epochs, he not only adorned it by a clear expository style and a lucid ordering of facts, but by his philosophic treatment, as it were, raised the subject to a higher plane of thought. Preeminently "the physical geographer of bygone periods," as he was most happily termed by Murchison, we may apply to him the well-worn but, in his case, most true phrase, *nihil tetigit quod non ornavit*. One paper only from his pen I will, in conclusion, especially mention, because, to my mind, it is most typical of all his work, namely, that "On the Possible Extension of the Coal-measures beneath the South-eastern parts of England." To myself, when first I read it years ago, it was like a revelation; it showed what stratigraphy might become when it was viewed in a comprehensive spirit,

and its facts were handled by a master in science: it proved the possibility of deciphering the physical history of the earth, even as its life-history was being reconstructed by the inductive labours of the palæontologist; so that we might hope to behold with our mental vision not only the strange forms which in long-past days had tenanted its waters and had moved upon its lands, but also the shores and the currents of its seas, the ridges and perhaps the mountains of its continents.

THOMAS WRIGHT was born at Paisley, in Renfrewshire, on November 9, 1809, and educated at the Grammar School in that town. After completing his articles with a surgeon, he entered as a student in the Royal College of Surgeons at Dublin, and was soon distinguished for his proficiency in anatomical and physiological studies; these, however, were interrupted by the injurious effect of a dissecting wound. This obliged him to decline an appointment which offered a prospect of a scientific career. After his restoration to health, he passed the College of Surgeons in the year 1832 and shortly afterwards entered upon the duties of his profession at Cheltenham, graduating as Doctor of Medicine at St. Andrews in 1864. His life was spent in active work, professional and scientific, in this pleasant Gloucestershire watering-place, where he held various appointments, among them that of Surgeon to the General Hospital. But the duties of his profession were not incompatible with an energetic pursuit of science. At first he devoted much time to microscopic work, but as this threatened to injure his eyesight, he turned his attention to palæontology. For this study the neighbourhood of his home then offered exceptional facilities, the numerous shallow excavations, many of comparatively ancient date, affording opportunities to the collector which can never again occur. Dr. Wright thus amassed a magnificent collection of Jurassic Echinodermata and Cephalopoda, which, I regret to learn, has not found a resting-place in his own country. He published several papers on the former Order in the 'Proceedings of the Cotteswold Field-Club' and the 'Annals and Magazine of Natural History,' which attracted the attention of Professor Edward Forbes. Before long it was arranged that, while the latter undertook to describe for the Palæontographical Society the British Cretaceous and Tertiary Echinodermata, Dr. Wright should do the same with the Jurassic. But the premature death of Forbes before he had commenced upon the Cretaceous Echinodermata, caused the Council of the Palæontographical Society to request Dr. Wright to undertake an additional labour and carry into effect the purpose thus left incomplete. The description of the Jurassic and Cretaceous Echinodermata occupied him for the greater part of his life, portions of the work appearing from the year 1855 to 1882; but in 1878 he commenced a description of the Lias Ammonitidæ, which was barely completed at the time of his death.

Dr. Wright was the author of about thirty-two separate papers on geological subjects, of which seven were contributed to our Journal; but the volumes above mentioned are the great work of his life and

an enduring monument of his extensive knowledge and energetic industry. He was zealous in promoting, by lectures and every personal effort, the advancement of science in his own neighbourhood. He was elected a Fellow of the Royal Society of Edinburgh in 1855, of this Society in 1859, and of the Royal Society of London in 1879, and he received acknowledgments from several foreign scientific societies. The Wollaston Medal was awarded to him in 1878.

His health began to fail nearly a year ago, and, after a lingering illness, he expired on November 17th last. But even suffering could not quench his enthusiasm for science. One evening, some months since, when death seemed to be very near, he roused himself and set to work on the revision of a proof-sheet, determined that, so far as lay in his power, he would not leave his task unfinished; and the last letter which he ever wrote was on the occasion of presenting to the Society a lock of Dr. William Smith's hair.

He was not rarely present at various scientific gatherings, where his stalwart form, cast in northern mould, distinguished him from the crowd, while his hearty tones and his genial manners made him ever a welcome guest. Those who have had the privilege of his friendship valued him not only for his great special knowledge, but also for his wide general culture and his sincere earnestness of character.

Searles Valentine Wood was born on February 4, 1830. Son of a geologist, Searles V. Wood, Senior, our former Fellow, so well known, to mention but one thing, for his great work on the Pliocene Mollusca, his attention was early directed to this science, and a community of interest, doubtless, formed one of the ties which bound father and son with a more than common affection. On the death of the former, his son undertook the duty of Treasurer to the Palæontographical Society, with which the two names will ever be inseparably connected. Mr. Searles Valentine Wood was brought up to the law, and practised for some years as a solicitor at Woodbridge, in Suffolk, but ultimately gave up his profession in order that he might devote himself wholly to scientific work. Tertiary and Post-tertiary geology was the chief subject of his study; and in 1864 he undertook, in company with Mr. Harmer, a careful examination of the Pliocene and later deposits of the east of England. These were all laid down with conscientious minuteness on the Ordnance Survey Map, Mr. Searles Wood taking as his share Essex and nearly the whole of Suffolk. The result of this work, so far as relates to the Newer Pliocene deposits (as they were termed by Mr. Wood), has been communicated to this Society in two elaborate memoirs, published in the volumes for 1880 and 1882. But numerous minor papers, in addition to these, were the result of Mr. Wood's untiring industry. Of course, in questions so difficult as are almost all those relating to the so-called Glacial Period, it is not to be expected that every conclusion of Mr. Wood's will find acceptance with his fellow

workers; but all must admire and gratefully recognize his patience and industry in the collection of facts.

For some years before his death his health was grievously impaired, but neither infirmity nor debility, nor even pain, could turn him from his beloved studies. His last contribution to our Journal, read at the opening meeting of the present session, was on the remarkable fossiliferous Tertiary deposit, not long since discovered, at St. Erth, near Penzance. A portion of that paper is printed in the current number of our Journal; but Mr. Searles Wood, in deference to the advice of friends, withdrew the list of species which he had given, in order that he might again present it with full descriptions of the more novel or more important forms. It will be remembered that, in the interesting discussion which followed, Dr. Gwyn Jeffreys spoke at some length against the view favoured by Mr. Wood as to the general equivalence of the deposit with some part of the Red Crag. We little thought then that in so brief a space both these accurate observers would have ceased from their labours. In concluding this too brief notice of a most earnest worker and most amiable man, I shall venture to quote a few sentences from a letter to Professor Judd, written by Mr. Searles Wood only a few days * before his death, because it seems to me to give unconsciously a far better portrait of the man than I could hope to draw.

Speaking of a recent severe attack from which he had in part recovered, but which was complicated by an ailment in one foot, he adds:—"This compels me to maintain a recumbent posture all day as well as night, but it has not prevented my renewing my close examination of the St.-Erth clay for several hours a day. This clay, however, is so sterile that I often work for days without finding a perfect shell or a fragment worth anything for determination; and I fancy that no one who had not perforce the leisure that I have, and a rather exceptional perseverance, would work at it as I am doing, and as I hope for many months yet to do." It was not so written: eight days later he passed away.

John Gwyn Jeffreys was born at Swansea on January 18, 1809, and early displayed a talent for natural history. At the age of nineteen he contributed to the Linnean Society a paper on the Pneumonobranchous Mollusca; and the study of this class formed at first the relaxation and afterwards the work of his life. He was elected a member of the Linnean Society in 1829, and of the Royal in 1840, not joining our Society until the year 1861. He was also an active member of the British Association, in which he held various offices, and in 1877 that of President of the Biological Section. At the last meeting, at Montreal, he contributed a valuable communication on the Mollusca of the two sides of the North Atlantic, which is being printed *in extenso* in the volume for 1884. From the University of St. Andrews he received the honorary degree

* Dated December 6, 1884.

of LL.D. He was educated as a solicitor, and for many years practised with much success at Swansea; but in 1856 he was called to the bar, and soon afterwards retired from business. He then settled at Ware Priory, in Hertfordshire, at which picturesque old mansion he resided till about four years since; thence, shortly before the death of his wife, he removed to London, and took a house at Kensington, where he died in consequence of an apoplectic seizure on January 24, after only a few hours' illness. On the previous evening he had been present at a lecture given by his son-in-law, Professor Moseley, at the Royal Institution; and he was among us at the Council-table, at the Geological Club, and at the Evening Meeting on the last occasion prior to his death. Indeed his mental powers showed no signs of failure, and a slight increasing difficulty of hearing was almost the only indication that he had numbered full 76 years.

The study of the recent Mollusca was the chief scientific work of Dr. Gwyn Jeffreys's life. He was one of the first to perceive the importance of dredging in the British seas; and after many years' experience in private enterprise, took charge, in 1869 and 1870, of the scientific work on board the 'Porcupine' during two of her cruises. Hence Dr. Gwyn Jeffreys's best scientific memorial will be his writings on the Mollusca, chief of which are his large and important work on British Conchology, and the papers, unfortunately left unfinished at his death, on the "Mollusca of the 'Lightning' and 'Porcupine' Expeditions," published in the 'Proceedings' of the Zoological Society; but his exact knowledge of recent forms gave his opinion an exceptional value on the fossils of the later Tertiary deposits, and on these subjects he has communicated papers, more valuable than numerous, to our Journal. But his other services to our Society must not be forgotten. For sixteen years he was its Treasurer, a position for which he was peculiarly adapted by his legal knowledge and habits of business, and the duties of which he fulfilled with great assiduity and invariable courtesy. He resigned that office four years ago, but at the time of his sudden death was still a member of the Council, having served on it continuously for twenty-one years. We shall for long miss his critical acumen and extensive knowledge, especially in any question relating to the later life-history of the earth; but we shall even more deeply regret the cheery, kindly friend, and the trusty adviser, who for so many years has been a familiar figure at these and many other scientific gatherings.

Alfred Tylor was born on January 26, 1824. His parents were members of the Society of Friends, and he was educated in schools connected with that body at Epping and Tottenham. At the age of fifteen, however, he entered the manufactory of brass and copper work belonging to his family in Warwick Lane. This early diversion from school to practical work was for Mr. Tylor the beginning rather than the end of his education. While singularly successful as a practical man of business, not only in the above factory, but also in

the colliery owned by his family at Tylorstown, in the Rhondda Valley, he found time to study anatomy for a period at St. Bartholomew's Hospital, and afterwards to become an accomplished geologist. But even this was not all: he was an earnest advocate for technical education, and devoted no small portion of his time to various duties outside his own business. He is the author of not a few papers, published in our Journal and elsewhere; and it may be mentioned that he was one of the first to doubt the authenticity of the celebrated Moulin-Quignon jaw. His most important and elaborate papers are devoted to questions connected with the action of rain, rivers, and ice; and he may be regarded as the author of the name "the Pluvial Period." Whatever opinions may be held as to the advantage of giving a special designation to the transitional interval between the Glacial epoch and that when the climate of the northern hemisphere finally arrived at its present condition, all must admit that Mr. Tylor did excellent work in drawing attention to the heavier rainfall which must have formerly prevailed, as well as in noting many interesting facts with regard to the various fluviatile deposits. His health failed during the last two or three years of his life, overmuch work having brought on renal disease; but, notwithstanding his malady, he was able to visit America in the autumn of 1884. On his return, however, his strength rapidly declined, and he died on December 31, "not so much from specific disease as from a collapse of the whole framework of life." He was married in 1850, and has left a widow and six children. It will be long before some of Mr. Tylor's work is forgotten in the annals of geology; but he has left another—may I not say a better?—monument in the regretful affection of many friends of his own standing, and in the enduring gratitude both of those less prosperous than himself, whom he liberally aided, and of not a few members of a younger generation, to whom, before they could help themselves, he held out a hand to give them that greatest boon, a fair chance in life.

James Buckman was born at Cheltenham in the year 1814. Designed for the medical profession, he studied in London, but not liking it, he returned to Cheltenham and commenced business as a chemist. But while in London he had evidenced a predilection for science, and had made a considerable collection of plants then found in the vicinity of the metropolis. In the year 1842 he was appointed to the curatorship of the Birmingham Philosophical Institute, where he remained till his election as Professor at the Agricultural College at Cirencester. There he worked assiduously for sixteen years, retiring in 1863 to a farm at Bradford Abbas, in Dorsetshire, where he died on November 23, 1884. He wrote a large number of papers on archæology, botany (especially agricultural), and geology, some of the last being contributed to our Journal; these dealt with questions concerning the palæontology and stratigraphy of the Jurassic series of the districts with which he was most familiar; the last, published in the 37th volume of our Journal, being "On the terminations of some Ammonites from the Inferior Oolite of Dorset and Somerset."

Richard Atkinson Peacock, formerly of Lancaster and St. Helier's, Jersey, died in London on February 2, 1885, aged 74. A civil engineer by profession, he took a great interest in geology, especially devoting himself to the causes of volcanic eruptions and earthquakes, and to the evidence of alterations in the level of the land in historic times. In the former he regarded saturated steam as the motive power, and on this subject he published at least one work. He was the author of a book on the sinking of the north and west coasts of France and the south-western coasts of England, published in 1868, and in the year 1876 read two papers before our Society on subsidence in Jersey and Guernsey respectively. It is to be hoped that the latter subject will not cease to attract notice now that we have lost Mr. Peacock, for it is one of much interest. I may, however, remark that for its investigation the acumen of the historical critic is even more necessary than the knowledge of the geologist.

Quintino Sella, elected a Foreign Member of this Society in 1881, died March 15, 1884. An admirable mineralogist and a sound geologist, a man successful alike in private and in public business, an accomplished statistician, statesman, and Minister of Finance, his death fell heavily on many circles and on many societies. To us he was known as a mineralogist, who, had he devoted himself wholly to that study, would have attained a place among the very foremost of the time; to another band of Englishmen his name was familiar as the President of the Italian Alpine Club; to others, again, as the President of the Academy of the Lincei at Rome; to those without our scientific societies, as the successful Minister of State and the restorer of his country's finances to a comparatively sound condition. Our generation has seen but few men of versatility so great, industry so untiring, and success so varied, few who could have been more widely regretted abroad or more deeply mourned at home.

Heinrich Robert Göppert, M.D., Ph.D., Professor of Natural History in the University of Breslau, died on May 18, 1884, at the advanced age of 84. He was elected a Foreign Member of our Society in 1857, and in 1883 was awarded the Murchison Medal in recognition of his labours in fossil botany. He was a man of unwearied industry, 245 papers from his pen being recorded in the List of the Royal Society, the first of them dating from 1828; his last work 'On the Flora of Amber,' a quarto volume, was published at Danzig in 1813, and an advance copy was forwarded to this Society, and laid on the table at the Anniversary meeting, when the Murchison medal was handed to his representative. In 1846 he received from the Academy of Sciences at Haarlem a gold medal and an award in money for his memoir on the Carboniferous Flora. The little band devoted to that most important but rather neglected branch of our science, Palæobotany, will feel that the disappearance from their ranks of Heinrich Robert Göppert is a loss not to be lightly repaired.

Ferdinand von Hochstetter, son of a clerical professor at Esslingen in Würtemberg, was born on April 30, 1829. Destined at first for his father's calling, he was led by his love of nature to adopt a scientific career, and studied at Tübingen under Prof. F. A. Quenstedt. After taking his doctor's degree, he proceeded to Vienna, where he made the acquaintance of Haidinger, and from 1853 to 1856 was employed on the geological survey of Bohemia. In the following years Hochstetter was absent from his native land, being engaged as one of the scientific staff on the well-known voyage of the 'Novara,' during which he quitted the ship for a time in order to study the geology of New Zealand and visit the Australian gold-fields. The results of his explorations are published in the first volume of the geological section of the work describing the expedition of the 'Novara;' and Dr. Hochstetter was also joint author of the small volume on New Zealand, a translation of which is in the possession of this Society. On his return he was successively Professor at the Vienna Imperial Polytechnic Institute, and Director of the United Imperial Museum of Natural History, in both of which he reorganized the collections. In 1880 he was elected a Foreign Correspondent of this Society. He was the author of a large number of separate papers and memoirs on mineralogical and geological subjects, besides a 'Manual of Crystallography' and one on Mineralogy and Geology; and he was the means of discovering pile-buildings and other remains of a prehistoric race on the margins of the lakes of Carinthia. Dr. Hochstetter was much esteemed by the Imperial family of Austria, and numbered the Prince Imperial among his pupils. His health had been for some time in a failing condition, and he died, much regretted by all who knew him, on July 21, 1884, leaving the reputation of an admirable geologist and an indefatigable worker.

The long and melancholy list is not yet ended. We lament, in sympathy with our geological brethren across the Atlantic, Alexander Murray, member of the Canadian Survey, to whom we are indebted for most of what we know of the geology of Newfoundland. We have lost also from the list of Members who have contributed papers, Mr. T. Curley and Mr. Joseph Colthurst, and but two days since came the heavy news of the death of Mr. J. F. Campbell. Born December 29, 1821, the eldest son of Walter F. Campbell, Laird of Islay, and cousin of the present Duke of Argyll, his prospects early in life were darkened by the loss of the family property during his father's lifetime, and thus he found himself, immediately after attaining his majority, thrown upon his own resources. This trial was borne with a quiet magnanimity which gained him the admiration of his kinsfolk and friends. He was called to the Bar, but never practised. From 1854 to 1860 he was successively Private Secretary to the Duke of Argyll and Secretary to the Board of Health, the Mines Commission, and the Lighthouses Commission, and from 1861 to 1880 he held office in Her Majesty's household. In the intervals of the above duties he travelled much. Iceland and

Scandinavia were more than once visited. In 1864 he went to America, describing the journey in 'A Short American Tramp,' published in 1865. In 1873–74 he travelled through the north of Europe to Archangel, thence through Russia to the Caucasus, and home by Constantinople and Southern Europe. In 1874–75 he made the journey round the world described in 'My Circular Notes;' and at later periods spent some time in India, Syria, Palestine, and Egypt. He contributed to our Journal papers on glacial subjects, and wrote also on the Parallel Roads of Lochaber and on the Gold Diggings of Sutherland. In addition to this he was an authority on Scottish Folk Lore. By geologists, however, he will always be best remembered in connexion with his book entitled 'Frost and Fire,' published in 1865, a work which bears evidence of his skill as an artist and accuracy as an observer, is full of quiet and quaint humour, is delightfully written, and, even when not convincing, is none the less suggestive. His loss will be deeply felt, for he bore equally well adverse and prosperous fortune, and "where he was best known, there he was also best loved."

The papers which have been presented during the last session have not, I think, been inferior in number or in interest to those of the preceding one. As in that, papers more or less stratigraphical have preponderated, and no lack of interest appears in those questions where the petrologist goes hand in hand with the field-worker; thus rocks igneous and rocks Archæan have received a large share of attention. Dr. Callaway read an elaborate paper bearing upon the relations of the older rocks of Anglesey. His assignment of certain fossiliferous strata to the Ordovician, rather than to the Cambrian, did not seem to command the suffrages of other workers in the same field; but it will be difficult, I think, to gainsay the evidence in favour of the Archæan age of the crystalline schists and so-called granites, which he brought forward in corroboration of that laid before you last year. Mr. Hill broke ground in a field comparatively new, whose rocks have long called for investigation by the more accurate modern methods, in his paper on the rocks of Guernsey.

My predecessor suggested, in his address last year, that there would be better chance of controversialists coming to an agreement on the difficult questions involved in the geology of the Archæan rocks, could they meet for discussion upon the ground. Provided that due precautions could be taken for preventing the melancholy consummation which was fatal to a well-known scientific society, there would be much, I think, in favour of this "trial by a mixed commission." But pending any such gathering of the clans on the Pebidian moorland, Dr. Hicks laid before the Society his rejoinder to the criticisms made in the previous session by the Director-General. As the forces of Jermyn Street had been concentrated on him, he not unnaturally sought the alliance of others, and Mr. T. Davies's petrological appendix to Dr. Hicks's paper forms a valuable contribution to the history of these interesting Pembrokeshire rocks. Some

of the questions involved in this controversy cannot be settled in the present state of our knowledge; but on two of great importance, the two most vital to his theory, viz. the great antiquity of the so-called Dimetian rocks and the separability of the Pebidian from the Cambrian, Dr. Hicks brought forward evidence which it is difficult to gainsay. Henceforth it will, I think, be admitted that the Dimetian cannot be regarded as an intrusive igneous rock of Palæozoic age; and that the Pebidian has, stratigraphically, at least as good a claim to be considered a distinct formation as the Lower Silurian of the Survey.

In anticipation of the meeting of the British Association in Canada, we received an excellent summary of the geology of the district traversed by the Canadian Pacific Railway from our old friend Principal Dawson, who is always a welcome visitor on this side of the Atlantic, and in whose well-earned additional dignity we all rejoice. Professor Green proposed a new reading for a well-known but admittedly difficult section at Llanberis. Mr. J. J. H. Teall has added to his reputation by his thorough and exhaustive paper "On the Chemical and Microscopical Characters of the Whin Sill," and that "On the Conversion of a Dolerite into Hornblende-schist." Professor Judd has found time amidst his pressing duties to give us another instalment of his investigations in Scotland in the paper read at our last meeting "On the Tertiary and older Peridotites of the Western Islands," a paper which will not only add largely to our knowledge of some very interesting rocks, but also be a most suggestive one to the petrologist. At an earlier meeting in my year of office Professor Judd also presented a supplement to his important paper on the Richmond boring, when contributions were read by Prof. Rupert Jones on the Foraminifera and Ostracoda, by Dr. G. J. Hinde on the Calcispongiæ, and by Mr. G. R. Vine on the Polyzoa obtained from the cores. A paper dealing with a cognate subject and of hardly less interest was that by Mr. J. Eunson on the range of the Palæozoic rocks beneath Northampton. The author laid before us the details of four borings in the Northamptonshire area, of which three had been observed by himself. At Kettering Road, one mile N.E. of Northampton, after passing through beds of the Inferior Oolite and the whole thickness of the Lias, about 67 feet of strata were traversed, which might represent some part of the Trias, after which beds of the Carboniferous series were struck at a depth of 805 ft. 6 inches and pierced for about 45 ft. At Gayton the beds assigned to the Trias were 61 feet in thickness, and these were followed by beds of more dubious age for 22ft. 6 inches, after which indubitable Lower Carboniferous Limestones and Shales were traversed for 190 feet, and were followed by red grits and marl, pierced for a depth of 105 feet. These rocks, be they Lower Carboniferous or Old Red Sandstone, or yet earlier, are certainly made up, in part at least, of the ruins of granitoid rocks, and are interesting as throwing light upon the probable source of many fragments of reddish grit in the Trias of the north-east of England. It seems to me not impossible that rocks similar in composition to these may have helped to constitute the ancient uplands which probably formed the eastern boundary of the river-valley in connexion

with which the lower members of the Trias were deposited. In the third boring at Orton, 12 miles N.E. of Northampton, only about 24 feet of rock occurred which could be possibly referred to the Trias, shortly after which a quartz-felsite was pierced, very similar in all respects to the rock at High Sharpley (Charnwood Forest), which I was formerly inclined to refer to an altered rhyolitic ash, but now feel more disposed to regard as a true lava, once glassy, but now devitrified, greatly crushed by subsequent pressure.

The remaining stratigraphical papers are not very numerous, and mostly rather brief. That by Mr. Downes on the Cretaceous beds at Black Ven has considerably augmented our knowledge of the basement-beds of the Chalk in the western area of Britain. Those by Mr. Starkie Gardner on the plant-bearing deposits in connexion with the basalts of Ireland and Iceland appear likely, when the whole evidence is published, to raise questions of importance as to the age of these deposits; and to the extremely interesting paper by Mr. Searles Wood on the no less problematical deposit at St. Erth, I have already referred. Mr. Lamplugh added largely to our knowledge not only of the fauna, but also of the stratigraphy of the interesting fossiliferous deposit associated with Boulder-clay at Bridlington. Boulder-clays themselves have been the subject of papers by Mr. Mellard Reade and Mr. Jukes-Browne; an interesting paper by Col. Godwin-Austen and Mr. Whitaker on a new railway-cutting at Guildford dealt with Post-tertiary as well as Tertiary geology; and Mr. Pidgeon brought us up to historic time by his communication on the submerged forest at Torbay.

On palæontology, we have had the pleasure of receiving three papers from our " Nestor " in that branch of geological study, Sir R. Owen. In that on *Rhytidosteus capensis*, from the so-called Trias of the Orange River Free State, he directed our attention to certain mammalian characters in the Labyrinthodont Amphibians, and in a later communication pointed out the resemblance between the teeth of the South-African *Tritylodon*, described last year by him and assigned to the Mammalia, and those of the Eocene mammal, *Neoplagiaulax*. In a third paper he described a portion of a skull of a youthful *Elephas antiquus* from Creswell Crags. Mr. E. T. Newton introduced to our notice a new species of Gazelle from the Forest bed; Mr. Miall described a fine specimen of *Megalichthys* from the Yorkshire Coal-field; and Prof. E. W. Claypole showed that in America he had detected the remains of Pteraspidian fishes at a lower geological horizon than they are known to occur in Britain. A new species of *Conoceras* has been described by a new contributor, Mr. T. Roberts; and Mr. Walford has given us a second of his carefully worked-out essays, in that " On the Stratigraphical Position of the Lower and Middle Jurassic *Trigoniæ* of North Oxfordshire and adjoining districts." Mr. Vine has treated of the Cretaceous Lichenoporidæ, and Prof. Duncan, Mr. Champernowne, and Mr. Tomes of various corals. Professor Hughes has reduced the number of extinct creatures by destroying *Spongia paradoxica*; while Dr. Hinde has shown us that it is possible to understand

even such a difficult family as the Receptaculitidæ. We received only one palæobotanical paper, strictly speaking, namely, that by Mr. Kidston, on *Zeilleria* and other forms belonging to the old genus *Sphenopteris*.

In addition to these, several papers were read on geological subjects without the limits of the United Kingdom, dealing with localities not only on the continent of Europe, but also in regions so remote as Japan, Australia, and New Zealand.

Turning for one moment from the work of our Fellows, as evidenced in our Quarterly Journal, we may assert with just pride that in other quarters also the intellectual activity of the Society exhibits no symptom of decline. Many by their contributions have aided Dr. H. Woodward in maintaining the high standard of that most valuable periodical the Geological Magazine, whose coming of age ought to be celebrated this year. The annual volume of the Palæontographical Society, edited still, as it has been so long and so well, by our Treasurer, Prof. Wiltshire, more than keeps up its high reputation, and both deserves and needs the support of all geologists. In it Baron von Ettingshausen and Mr. J. Starkie Gardner continue their work on the Eocene Flora; Professor Rupert Jones, with his *collaborateurs* Messrs Kirkby and Brady, neither of whom have we the pleasure of counting among our Fellows, conclude their monograph on the Carboniferous Entomostraca; Dr. Woodward completes the description of the Carboniferous Trilobites; Mr. Davidson, the supplement to the British Brachiopoda, bringing thus to an end, at any rate for a time, a work of inestimable value to every student of geology; and the volume ends with the seventh part of the description of the Ammonites of the Lias, the last contribution which we shall ever receive from the pen of our departed friend Dr. T. Wright. Mr. Bauerman has published a most useful 'Manual of Systematic Mineralogy,' thus completing his treatise on the subject. The large and exhaustive volume on ore-deposits entitles Mr. J. A. Phillips, our Vice-President, to the gratitude of all students of that difficult branch of our science; Professor P. M. Duncan has revised and augmented the fourth edition of Sir Charles Lyell's 'Student's Manual of Geology;' and the first volume of the late Professor Phillips's 'Manual of Geology,' treating of Physical Geology and Palæontology, testifies the care and the erudition of Professor Seeley. On this the editor has expended fully as much labour as would be needed for the production of an entirely new book, and it is impossible to praise too highly the research which it evidences. It is far more than a text-book, it is a directory to the student in prosecuting his investigations. We await impatiently the second volume, on Stratigraphical Geology, which is in charge of our friend Mr. R. Etheridge, sometime President of this Society. Lastly, we have just received from the British Museum a copy (in advance) of Mr. R. Lydekker's Illustrated Catalogue of the Fossil Mammalia (Part I.), and also a copy of a small illustrated Guide to the Fossil Fishes by Dr. H. Woodward. Both these books are placed upon the table.

But the event of primary importance in geology during the past year has been the abandonment on the part of the Director General and other officers of the Geological Survey, of the Murchisonian hypothesis concerning the stratigraphy and the age of the metamorphic rocks of the Central Highlands. In his letter, published in 'Nature,' Nov. 13, 1884, the Director General, "spatiis conclusus iniquis," was prevented from indicating the share which previous writers had taken in bringing about this result; but as in these later days the "morning stars" of this reformation have arisen from our Society, and for the most part scintillated in our Journal, you will, I am sure, pardon me if I dwell briefly on the dawn before sunrise. Great as our gratitude should be to those who bring us the perfect light, we should not forget their harbingers in darker times, even if they could not wholly disentangle themselves from the mists of error.

The view that the crystalline schists of the Central Highlands * were, in the main, metamorphosed representatives of Lower Silurian strata, set forth in fullest detail in the classical papers of the late Sir R. Murchison and Dr. A. Geikie, was always stoutly resisted by the late Professor Nicol; but the authority of its upholders and the perspicuity of their arguments prevailed with the geological world, and opposition seemed to have expired with the death of Nicol. The Murchisonian hypothesis was endorsed by every official publication; it permeated our text-books. The first to raise the standard of revolt against authority was Dr. H. Hicks, who has devoted himself to the identification of Pre-Cambrian rocks which have been absorbed into and annexed by later formations, and their restitution to Archæan, with as much energy as, and better success than, some ethnologists have displayed in the discovery of the "lost ten tribes." In our Journal for the year 1878 (vol. xxxiv.), Dr. Hicks published a paper "On the Metamorphic and Overlying Rocks in the neighbourhood of Loch Maree, Ross-shire." In this, while agreeing with Sir R. Murchison and Dr. A. Geikie that there was an ascending succession from the Hebridean series, through the Torridon sandstone, quartzites, and limestones to the flaggy series (called by those authors the Upper Gneiss), and an intrusive mass of syenitic rock (exposed on the floor of Glen Logan at the base of the last named), he maintained that they were mistaken in supposing the so-called Upper Gneiss, exhibited on the left bank of Glen Logan and in the lower part of Glen Docherty, to be a metamorphic group, and had overlooked the fact that true metamorphic rocks belonging to the oldest or Hebridean series reappeared in the floor of Glen Docherty, and by gradually rising and probably upfaulting, formed the whole mass of Ben Fyn, whence they passed southwards to constitute the major part of the Central Highlands.

In the volume for 1880 appeared a paper entitled "Petrological

* An excellent sketch of the earlier stages of the controversy as to the age of the rocks of the Scotch Highlands is given by Mr. W. H. Hudleston, in a paper read to the Geologists' Association in 1879, and printed in Proceedings Geol. Assoc. vol. vi. p. 47.

Notes on the vicinity of the upper part of Loch Maree." The author, after emphasizing certain stratigraphical difficulties to which attention had been called at the reading of the last-named paper, expressed his opinion, founded on microscopic study, that the flaggy beds, regarded as unaltered Lower Silurian by Dr. Hicks, were rightly called metamorphic and were true schists, although very different in character from the admitted Hebridean rocks; he stated also that he had been unable to recognize any distinction between a newer and an older series in Glen Docherty, the former appearing to pass on from its escarpment at the upper end of Loch Maree towards Ben Fyn, although certainly the rock became more highly metamorphosed in this direction. The author accordingly contended that Dr. Hicks had failed to make good his criticism against the Murchisonian hypothesis. He asserted, however, that previous observers were in error in supposing the "syenite" of Glen Logan to be an intrusive mass of igneous rock, and maintained, on stratigraphical and petrological evidence, that it was simply a portion of the Hebridean floor brought up into its present position by faults *.

The controversy was now transferred to the pages of the 'Geological Magazine.' Dr. Hicks obtained the valuable aid of Mr. T. Davies to examine his specimens microscopically, and published a series of papers in the volume for 1880 (vol. vii. dec. 2). In these he maintains the general accuracy of his former views, insisting much on the identity of the Ben Fyn schists with those of admittedly Hebridean age at Gairloch; a point which, though obviously of primary importance in the argument, had unaccountably in his former paper been passed over almost in silence. He also admitted that the so-called syenite of Glen Logan was not intrusive in the Lower Silurian strata, though he still regarded it as an igneous rock, but of Pre-Cambrian age, and he modified the section, which had been most open to criticism, so as to weaken the main objections. To these papers his critic briefly replied, commenting upon what appeared to him the weak points of the defence, and expressing more clearly his own position in the following words, "It is possible there may be very much Pre-Cambrian rock in the Scotch Highlands; my contention is that Dr. Hicks's proof of this is erroneous."

Another paper was read by Dr. Hicks before our Society upon the age of the Scotch Highlands, which, however, was subsequently withdrawn by the author, so that only a short abstract appears in the volume for 1880; but I believe the substance of it was afterwards embodied by him in an address to the Geologists' Association. In this Dr. Hicks deals with the district for a considerable distance on either side of Loch Linnhe, Loch Eil, and the S.W. end of the Caledonian Canal. He shows that here also a great series of rocks occur corresponding with those of Hebridean type, both as asserted by himself and as admitted by his opponents, with which are infolded both a schistose series, which he is disposed to correlate with

* The possibility of part of this being gneiss had already been suggested (without the knowledge of the writer of the above paper) by Mr. Hudleston in his communication to the Geologists' Association.

the Pebidian of Wales, and a group of rocks comparatively unaltered, which he regards as Silurian.

In the volume for 1881 a new combatant appears, and the debate is transferred to another region. Dr. C. Callaway, in a short paper on "the Limestone of Durness and Assynt," comes to a conclusion which perhaps may be most simply expressed in his own words. He had selected the localities "because they alone are alleged to have yielded fossils from the limestone, and because Murchison regarded them as of primary importance in the construction of his argument. My researches," he says, "led me to the conclusion, not only that the sections were broken and therefore untrustworthy, but that the relations of the several rock groups were inconsistent with the supposition that the limestone passed below any part of the newer metamorphic series." In another short paper published in the volume for 1882 he asserts the conformity of the quartzite with the Torridon Sandstone in the Loch Broom and Loch Assynt region, and on that ground maintains that the latter has more claim to be referred to the lower part of the Ordovician than to the Cambrian series. In a paper entitled "First impressions of Assynt," published in the 'Geological Magazine' for 1882, Mr. Hudleston insists strongly on the evidence of folding and faulting on a vast scale, doubting the existence of the "Upper Quartzite," and bringing forward numerous reasons for believing that the equivalent in that district of the "syenite" of Glen Logan was, "from top to bottom, the local representative of the fundamental gneiss, or something that is first cousin to it."

In the volume for 1883, Dr. Hicks returned undaunted to the attack, and, in the chivalrous spirit of one who fights for truth rather than for victory, took his old antagonist into his confidence, and obtained his aid in the examination of his collections. In this paper, which deals with an extensive district on the western side of Scotland, between parallels of latitude drawn roughly through Fort William on the south and the lower end of Loch Maree on the north, Dr. Hicks gives the results of two journeys undertaken subsequently to the year 1878, and brings forward very strong evidence in favour of the following conclusions:—that in the district between Loch Maree, the Gairloch, and Loch Torridon, the admittedly Palæozoic beds (Torridon Sandstone, Quartzites, &c.) rest upon the Hebridean series, which exhibits in ascending order three lithological types; the lowest or most massive being exposed on the east shore of Loch Maree; the middle or more banded gneisses occupying a considerable area on the west shore of the same loch, and a strip between the head of the Gairloch and the lower part of Loch Torridon; and the upper or micaceous schist-like group occupying a strip which, starting from Ben Alligin, runs northward to the head of the Gairloch, separating the two areas of the last-named group. That the whole of the series is included in the Hebridean of Murchison has never been questioned. Dr. Hicks then points out that a group of rocks lithologically corresponding with the last-named of these passes by Loch Fannich and the head of Glen

Logan, through Ben Fyn and the district east of it, and so broadening out occupies the coast from Loch Ailsh to Arisaig. Again it reappears, on the eastern side of a fault, near the head of Loch Eil (on the northern shore of which is a small area of Torridon Sandstone), extending to Fort William on the Caledonian Canal. The triangular space between these two districts was occupied, as he showed, by a series of rocks corresponding lithologically with the middle zone of the Hebrideans of the Loch-Maree region. To these three lithological groups Dr. Hicks gave the names respectively of the Loch-Maree, the Loch-Shiel, and the Gairloch or Ben-Fyn series, and he inclined to hold them stratigraphically distinct one from another. Dr. Hicks also admitted in this paper the gneissic character of the so-called syenite of Glen Logan, and classed it with the Loch-Maree group, stating that in the upper part of the glen he had found that it abutted on rocks belonging to the Ben-Fyn group.

The perplexing schists on the southern side of Glen Logan (named by him the Glen-Docherty beds, which occupy a considerable area on either side of the latter glen) are separated from the rest, and their age is left by him in uncertainty. It cannot be denied that in this paper Dr. Hicks made to the controversy a contribution of the highest value, and may claim to have brought Highland reform into the region of practical politics. He had shown that unless lithological similarity was to be utterly disregarded as a factor in correlation in two areas almost neighbouring, a very large portion of the western Highlands north of the Caledonian Canal was occupied by rocks which were substantially identical with an important series of admittedly Hebridean age, and exhibited the same lithological sequence.

But this was by no means the only blow dealt in the course of the year. Three months later was read a third communication from Dr. Callaway, printed in the same volume, "On the Age of the newer Gneissic Rocks of the Northern Highlands." This elaborate paper was the result of work done chiefly during the summers of 1881 and 1882, in the districts around Lochs Broom, Assynt, and Erriboll.

The following is a summary of Dr. Callaway's principal conclusions:—

(1) The "Upper Quartzite" of some authors is, in these districts, simply a repetition by folding of the so-called Lower Quartzite; the "Upper Limestone" on Loch Ailsh is marble and crystalline dolomite in the Eastern-Gneiss series (Upper Gneiss of Murchison); the Assynt series (Palæozoic) has been doubled back upon itself in a compressed synclinal fold along Loch Erriboll, while along Loch Broom the dolomite (of the Palæozoic series) does not come into contact with the Eastern Gneiss at all, but is separated from it by older faulted rocks.

(2) In the three areas described the Assynt series and the Eastern Gneiss display a discordant strike and dip.

(3) The "igneous rock" of some authors, that now commonly

referred to as the Logan* rock, is usually the Hebridean Gneiss, which is often brought by an overthrow fault above different members of the Assynt series.

(4) The Eastern Gneiss, though actually overlying the Assynt series in some localities, has been brought into this abnormal position by earth-movements subsequent to the deposition of the latter, and belongs to the Archæan group, but is nevertheless widely separated in age from the Hebridean.

In his earliest paper Dr. Callaway had been disposed to acquiesce in the view which for a time found favour with several investigators, myself among them, that the apparent sequence from the base of the Torridon Sandstone to the Upper Gneiss might be a real one, but that the fossiliferous limestone of Durness might not be identical in age with the dolomitic limestone which appeared to underlie the Upper Gneiss, hence that the rocks from the Torridon Sandstone to the Upper Gneiss inclusive might all belong to the Archæan series, though to a later part of it than the Hebridean. This view Dr. Callaway, after more detailed work, was compelled to abandon, and I am myself convinced that we must accept the Torridon Sandstone, quartzite, and overlying limestone, whether dolomitic or not, as deposits of Palæozoic age.

But the untenability of the Murchisonian hypothesis had been simultaneously demonstrated by yet another investigator. Professor Lapworth, whose work in the southern uplands of Scotland had rendered him especially familiar with disturbed districts, and with the principles of mountain as opposed to lowland stratigraphy, applied himself in the summer of 1882 to the study of the coast region of Durness and Erriboll, selecting that as the one in which "a demonstrably ascending succession from the basal Hebridean Gneiss through fossiliferous Palæozoic limestones into the metamorphic gneiss and micaceous schist and slates† of the Central Highlands" was asserted to occur. The results of this work have been only in part published, because, on revisiting the country in the summer of 1883, incessant labour and continuous exposure completed the ill effects of a long period of excessive devotion to work, and brought on most serious illness, from which Professor Lapworth has hardly yet completely recovered. But you will remember that he exhibited in this room a most elaborate map and sketch section, at the meeting when Dr. Callaway's paper was read‡, and showed how his detailed work in the Erriboll region was in accordance with the main conclusions at which that investigator had arrived. Professor Lapworth, however, in the course of the year 1883 contributed three papers to the Geological Magazine, entitled "The Secret of the Highlands." These papers, the first of which was published in the March number, I may venture to assert will always hold a very high place among the contributions to the elucidation of a problem which for so long has been the special "crux" of British geologists. In the first, Professor Lapworth

* Named from Glen Logan, near Loch Maree, also written Glen Laggan.

† The Upper Gneiss of Murchison and Geikie.

‡ May 9, 1883.

demonstrates, by a sketch of the geology of the Durness-Erriboll region, that the ordinary principles of stratigraphy would lead observers in two adjacent districts to absolutely contradictory results viz. that in the Durness area, the Sutherland (or Newer) Gneiss series is demonstrably *newer* than the (fossiliferous) Palæozoic series, and in the Erriboll area is demonstrably *older*. In the other papers, published in the May and August numbers (the series was, I believe, left incomplete through his illness), he proceeds to apply to the Scotch Highlands the principles of mountain stratigraphy enunciated by Rogers, Heim, Baltzer, and others, and shows how, in the process of folding, inversions and overthrust-faults may be produced on a gigantic scale, and appearances of conformable succession and even of bedding be simulated, which are nevertheless wholly deceptive.

The matter, then, before the end of the year 1883, in the summer of which a detachment from the Geological Survey took the field in Sutherland, stood thus: two or three of those whom I may call the minor contributors to this controversy, had pointed out serious mistakes and unsuspected difficulties, and had expressed, in effect, this opinion, that very clear evidence would be needed before we could accept the dominant rocks of the Highlands as of Lower Silurian age. Dr. Hicks had shown that unless lithological similarity in neighbouring districts be of no value, a very large portion of the rocks in the mountain region of South Ross-shire and Inverness must be much older than the Torridon Sandstone, and that there was evidence of faulting and folding on a gigantic scale. Dr. Callaway had shown the same for the western part of Sutherlandshire, and had proved the existence of unsuspected inversions and overthrusts; while Professor Lapworth had demonstrated the Murchisonian hypothesis to be self-contradictory in a region regarded by its upholders as typical, and had shown us that the difficulties, anomalies, and deceptive appearances are such as are usual phenomena in mountain-making on a grand scale*.

I have dwelt but little upon the discordances or the errors of the observers whose work I have noticed. Perfect concordance among reformers is not to be expected; and men who are honestly struggling towards the light cannot hope to attain at one bound to the complete truth. There is always a danger lest the fascination of a new discovery should lead us too far. Men of science, being human, are apt, like lovers, to exaggerate the perfections and be a little blind to the faults of the object of their choice. Even now, great as has been the flood of light thrown upon the question by the writings of the Director General and his officers, I am sure that they would be the last to indulge in the illusion that they have solved every mystery or may not have to correct some details. It

* I have omitted in the above brief sketch several papers of minor importance which have appeared in the 'Geological Magazine' and other publications, and a series of papers by Prof. Heddle in the 'Mineralogical Magazine;' the latter, because, notwithstanding their value as contributions to the mineralogy of the Highlands, I do not think they help us much in the elucidation of the above-named problem.

will need years of careful mapping in the field, supplemented by minute study of the rocks by practised and qualified microscopists (for in this matter a very special training is needed), before the whole secret of the Highlands is discovered. I am, indeed, more hopeful of the possibility of distinguishing between the results of metamorphic action in Palæozoic and in Archæan times than I believe some workers in this field to be; but to this subject I hope to return if honoured with another opportunity of addressing you from this chair. However, whatever may be the results of future work, whether official or non-official, I do not hesitate to say that this abandonment on the part of the Geological Survey of the Murchisonian hypothesis is an event of primary importance in the history of geological progress; and we should render a just tribute of admiration to the Director General and to Messrs. Peach and Horne, the chief members of the field-party, for their candour in investigating the question and in announcing their abandonment of opinions which only a few years since it would have seemed presumptuous to question. When Dr. Geikie declares that an hypothesis, maintained by one whose memory is justly dear to him, in the support of which he himself in his younger days played an important part, must be abandoned, he shows himself superior to that too common weakness which fears to admit a mistake, and he gives us the best hope for the future of the Geological Survey of Great Britain.

Indeed, the importance of this step can hardly be over-estimated in regard to its future results. As a worker in petrology, I can testify how the Murchisonian hypothesis has lain like an incubus on the investigator, impeding his progress in what seemed legitimate inductions from observed facts, and being invoked by his opponents as a kind of fetish. Its abandonment, therefore, will be of moral as well as of intellectual value. I have noticed, sometimes with regret, among geologists an over-tendency to hero-worship. To question the conclusions of one of the great men now departed from among us has been regarded as savouring of presumption. We are right, in the interest of science, to scout criticism which is founded on ignorance, and to show little mercy to rash hypothesis; for these, by cumbering the ground, retard instead of helping progress; but a spirit of blind adoration for the past should have no place among those who are seekers after truth. So long as the facts are unaltered we are right in hesitating much before we differ from conclusions which one of our departed worthies in science has formed upon the data which were submitted to him as fully as to us; but when new facts have been discovered, when novel and more perfect methods of investigation have been devised, we are bound, as honest men, to make full use of these and not to shrink from announcing our conclusions. I yield to no one in reverence for our great men of old; I marvel humbly at what they accomplished with the means at their disposal; but I should think it a wrong to the memory of searchers after truth did I invoke their names to arrest its progress, and use the "dead hand" of the departed hero to paralyze the living worker. There is no revelation in science;

discovery did not cease when either De la Beche, Murchison, or Sedgwick rested from their labours; and it needs no prophet to foretell that in the days to come others will "rise on stepping stones of *our* dead selves to higher things."

Another good effect on geological progress is likely to result from this honest recantation. The establishment of a Geological Survey as a department of the State is an immense boon to a country; but there is always some danger lest the systematic method of their work, and a natural, I may say laudable, *esprit de corps* should lead its members to regard workers unconnected with them as intruders, and to speak with some contempt of "amateurs." Personally I should not admit that a man who has devoted his life to the study and teaching of geology is not as fully entitled to be called a Professional Geologist as one who is an officer of a Survey. Indeed it appears to me that in the two ranks you will generally have developed capacities equally important, which can very rarely be united in any one man. The official surveyor obtains knowledge of great accuracy and minuteness in a field which, from the nature of the case, must be rather limited; hence he becomes what we may call a specialized stratigraphist; or, if not, he must occasionally be set to execute work for which he is imperfectly qualified, and so may make serious mistakes. The unofficial geologist, unfettered by the requirements of an office and the necessity of returning a seemly annual report of progress to his paymasters, the State, is able not only to follow his special bent, but also to extend his experience over a wider area. Travel, as it has been well said, is an essential in the education of a geologist; but to travel much requires a more liberal allowance of time and of stipend than can be obtained from an English Government. But accepting for a moment the definition of a professional geologist, as commonly understood, there is and has been sometimes a danger that the class-feeling of which I have spoken should be aroused. It would be an ill day for science if the Geological Survey should ever become so narrow-minded as to resent *ex officio* the criticism of unattached competent observers, or one of the latter find any special pleasure in dilating upon a chance mistake which bore the *imprimatur* of Jermyn Street. It would be the greatest disaster if the votaries of geology became divided into "an establishment" and "nonconformists," and imported into their differences a spirit too prevalent in theology. Messrs. Peach and Horne, by their unprejudiced investigation into the facts in the field, and the Director General by his frank admission of a past mistake, have done their best to close a rift of which I have sometimes observed indications. In the future it will be evident that all alike are liable to err, and that the discovery of truth is not limited to any age or any workers. Science needs no infallible church and admits of no Pope.

On these occasions you have for long past tacitly indulged your President with an opportunity of making some remarks on any department of geology in which he is specially interested. Of this

indulgence I intend to avail myself by selecting petrology*, because of late years I have more especially devoted myself to investigating that branch of geology. In so doing I cannot hope to command the sympathies of more than a limited portion of my audience; but I venture to think that it may be of use to state, as clearly as may be in my power, some of the results at which I think petrologists have arrived, and some of the difficulties which yet remain for solution. It will not, however, be my purpose to endeavour to ascertain whether the former category commands a majority of votes among geologists, or even among nominal petrologists; I shall venture to speak, as it has been my habit to work, with considerable independence, and you must receive my remarks as mainly the expression of my own opinion, which, however, I can assure you, in all matters still the subject of controversy, has not been formed without considerable thought and labour. This method of procedure has been rendered inevitable by the circumstances of the case. It is now some fourteen years since, owing to a combination of causes, I drifted into studying the microscopic structure of rocks. I say "drifted," because I did not undertake the study deliberately, nay, I refrained from it for some time through fear that a certain delicacy in my eyes would make it impossible for me to work with the microscope. That fear, however, has happily proved to some extent groundless, though I have always had to exercise considerable caution, and to use high powers only for limited times. I began the study in consequence of finding among those who professed to be authorities such a conflict of opinion, even upon the most fundamental questions, that no conclusion, upon written evidence alone, seemed possible. Hence it has always been my endeavour to work without prejudice in favour of any view, to gather my facts from observations both in the field and with the microscope, to frame hypotheses as the facts accumulated, and then to continue to test these hypotheses by further work. I believe that I may add that, at the beginning, I always took as the more probable hypothesis that which appeared to find acceptance with the best authorities. I have endeavoured, in short, to apply to this branch of geology the laws of reasoning which were taught me years ago in mathematics, and I venture to believe that this method is the safest. It will not save one from mistakes; it may happen that, notwithstanding all care, one generalizes too hastily; a wider knowledge may show that an hypothesis is inadequate or imperfectly stated; but still, I believe that this method of successive approximations, of framing working hypotheses from facts, and constantly exposing these to the test of new facts, is the right way to attain truth in science.

Let me, however, first venture one or two remarks on the present position of petrology as a branch of science. It has undergone vicissitudes. To many of the early geologists it presented great

* Or, as some authors prefer to call it, petrography. The word used in the text appears to me preferable on the analogy of the other designations of sciences, petrography indicating the description rather than the scientific investigation of rocks.

attractions, and for a time palæontology was of less account than mineralogy, the fossil contents of the earth's crust attracted less attention than its mineral structure. But some forty years ago the majority of geologists yielded to the fascination of the vast field which a study of fossils opened out before them ; and exact petrology, at any rate in England, found few followers after the death of De la Beche. I do not say this as a reproach—it is well that each generation should do the work which lies ready to its hand ; and I can understand that the great mystery of life will always induce (and, I may say, rightly induce) the majority of thoughtful men to incline to a study of the organic rather than of the inorganic world. Further, the older generation of petrologists had gone about as far as was possible with the means at their disposal ; the revival of petrology has been due to the application of the microscope to the investigation of its problems. In this respect we may feel a just pride in remembering that to one of our countrymen, Dr. H. Clifton Sorby, a former occupant of this chair, belongs the honour of being among the very first to appreciate the importance of this mode of investigation and to place himself at its head.

At the present time the study of petrology is encompassed with not a few difficulties, some inherent, some temporary. It may be useful, even at the risk of giving offence, if I glance briefly at these. To begin, the study is not, and can hardly ever be, a popular one. To be an ideal petrologist it is necessary to be a good chemist, physicist, mineralogist, and field-geologist ; and who can hope to combine qualifications so diverse? Again and again I have found myself sharply stopped by my ignorance of chemistry, of physics, or of mineralogy, or by want of leisure to undertake a long journey for the purpose of study in the field. These difficulties, however, will always more or less exist, and we must be content to do our best with the means at our disposal. But there are also difficulties of a more temporary nature. One is that geologists, as a body, undervalue rather than overvalue the difficulties of the subject, and seem disposed to treat it as a playground whereon they may relax from severer studies. As regards this, I venture to assert that, at the present stage of our knowledge, crude fancies and vague hypotheses, founded on a few imperfectly observed facts, can do nothing but cumber the ground and impede the progress of students. No observation on any point of real difficulty is of the slightest value unless it be substantiated by careful study with the microscope.

Closely akin to this is another difficulty, that the evidence cannot be presented *ad populum*. What is seen with the microscope depends not only upon the instrument and the rock-section, but also upon the brain behind the eye of the observer. Each of us looks at a section with the accumulated experience of his past study. Hence the veteran cannot make the novice see with his eyes ; so that what carries conviction to the one may make no appeal to the other. This fact does not always seem to be sufficiently recognized by geologists at large. In similar palæontological questions, such as the structure of plants or of protozoans, I have

observed that the opinion of one who is known to have devoted some years to the study is considered to outweigh that of one who has given no proofs of competency; while I have seen in petrology, again and again, statements commanding attention, and even printed in scientific journals, which I knew not only to be unproved, but also, unless the work of years had been wasted, to be extremely difficult to prove.

There is yet another impediment to progress, quite opposite to, and much more laudable than, the last. It is that the recognition of the great difficulties of the subject causes some students to despair of arriving at the truth, and leads them to adopt what I may call an agnostic position. Now I believe that by so doing no progress ever has been or ever will be made in science. If caught in a scientific "slough of despond," you will never get out by merely wallowing about aimlessly. Assume that there is a way out; try in turn each that seems most probable, and probably one will be found. I am well aware that there are a vast number of questions in petrology which are not yet settled—not a few, perhaps, never will be settled in our lifetime; but I maintain that progress is most likely to be made by endeavouring to frame a working hypothesis, if only the observer be strictly honest in recording not only the facts which are favourable to it, but also those which appear to be hostile. May I then be allowed, before proceeding further, to lay down two principles which occasionally seem to be forgotten by some earnest workers?

(*a*) The first is that all observations which are on record are not of equal value. This depends, as I have said, partly on the qualifications of the observer, partly on the perfection of his appliances. For example, there are some difficult points in petrology in regard to which I should attach hardly any weight to the evidence of even one of our most honoured workers in "premicroscopic" days, because I know, from my own experience, that the question is one where the unaided eye cannot help us to a decision.

(*b*) That one "positive" observation outweighs a large number of "negative," the latter word being used in the sense of "leading to no definite conclusion." Let me illustrate this by an example. Suppose I wanted to ascertain whether an igneous rock were interbedded with or intrusive among certain sedimentary strata, and that twelve sections were to be found. Suppose that in eleven of these the appearances were not inconsistent with either interpretation, but that at the twelfth the evidence could only lead to one of the two views. Clearly the absence of conclusive evidence in the eleven cases would not affect the value of the evidence in the twelfth.

The rules, in short, of ordinary reasoning—and this remark has a wider application than to the case which I have just mentioned—hold in every branch of science, and in no one is it more needful to bear them in mind than in geology, where direct experiment (as in chemistry and physics) is so often impossible, and where we can never attain to more than a degree of moral certainty.

With these preliminary remarks, for which I trust I may be pardoned, as they are the outcome of an experience gained during some eight years in your service and some fourteen in petrological work, I turn to the special subject which I intend to discuss briefly to-day —the classification and structures of the igneous rocks.

By an igneous rock I mean, of course, one which has been in a state of fusion through heat. This fusion, however, differs from that which has been undergone by most rocks artificially produced, such as slags, because it has always taken place in the presence of water; and further, the material has often solidified, and even crystallized, not only without the expulsion of, at any rate, all the water, but also under considerable pressure. Probably the nearest approach to solidification under conditions similar to that of a slag is given in the case of lavas, immense volumes of steam being generally disengaged from the flows as they are emitted from a volcano. I draw attention to this at the outset, because I think it possible that it may prove to be a matter of primary importance in certain of our investigations.

We ought, however, before proceeding further, to glance at two objections which might be started *in limine*.

(1) That no classification is possible, because nature has not made distinctions; she is too protean to be bound by our fetters.

(2) That it is impossible to draw a hard and fast line between igneous and sedimentary rocks, because the former are frequently only the result of metamorphosis of the latter carried to an extreme degree, so that the one series passes gradually into the other.

As regards the former of these objections, we may remark that on the assumption that igneous rocks have solidified from a state of fusion (whether part of the original magma of the earth or stratified rocks subsequently melted), we should anticipate difficulties in classification, and not expect to find very sharply defined lines of separation in either chemical or mineral composition. This difficulty, however, is not confined to petrology; the biologist, for instance, is not deterred by the admitted difficulty of distinguishing a species from a variety, or of deciding whether species have an independent origin. Hence, for all practical purposes, species exist alike for the most thorough-going evolutionist and the most confirmed believer in special creations. Classification is a necessity if progress is to be made; distinction of things is needed for distinction of thought; and over this difficulty we need not linger, for we shall find that, practically, although intermediate forms may exist, the majority of rocks can be grouped around certain types.

The second objection may receive a like answer; and I may add further, that if we agree upon certain characteristics as denoting an igneous rock, the antecedent history of the rock (for our special purpose) becomes immaterial. For instance, I can think of a piece of glass as an (artificial) igneous rock, even though I may have formerly seen a crucible full of the material from which it has been made.

There are, moreover, as it appears to me, two rather considerable

difficulties of a general character in this supposition of the derivative character, as I may term it, of igneous rocks*. The one, that chemically and even mineralogically there is a remarkable identity between igneous rocks of the most diverse geological ages. This, however, I content myself with mentioning, because I can more conveniently enlarge upon it at a later period. The other, that the chemical composition of the bulk of sedimentary and of igneous rocks is too diverse to admit of the hypothesis of derivation being generally true. It is possible, I allow, to find certain sedimentary rocks which chemically are nearly identical with certain igneous; but to do this we must select exceptional cases in the one to compare with general instances in the other,—the most marked difference being in the percentage of the alkaline constituents, which leads, as is well known, to the presence of such silicates as staurolite, andalusite, cyanite, and alumina-garnet, in indubitably metamorphosed sedimentary rocks, instead of some members of the felspar group. Further, the argument of chemical identity holds only among the more acid of the igneous rocks; among the sedimentary it would not be easy to find representatives of the dolerites and basalts, rocks extremely abundant in nature, and almost hopeless to parallel the peridotites, which in one form or another are by no means rare. I glance only at the corroborative evidence of meteorites, because I intend on the present occasion to limit my remarks to rocks of terrestrial origin, though I am quite aware that any system of classification for the latter must be extended to the former.

The tendency to a definite order of succession among the igneous rocks which has been remarked by many observers, appears to me more favourable to the idea of these rocks being integral portions of the inner part of the earth, than to their being the result of the local melting-down of sedimentary strata. This subject is so full of interest that I would gladly have discussed it, but the difficulties still inherent in it, and the collateral disquisitions into which it would lead, prevent me on the present occasion. I do not, indeed, think that we can accept subdivisions so elaborate as those proposed by Richthofen, and used by Dutton† in his ingenious explanation of the apparent anomaly of basalt, an easily fusible rock, being commonly later in date than rhyolite in a series of eruptions; but undoubtedly we do so frequently find this general order—andesites, sanidine-trachytes (probably these two will often be intermixed), rhyolites, and basalt, and observe gabbro cutting peridotites—that these sequences can hardly be accidental. It may suffice, then, to call attention to Captain Dutton's valuable dissertation and to two papers by Mr. Teall (which appeared just after the reading of this address) wherein this subject is discussed more fully‡.

* The frequent occurrence of sharply defined junctions between igneous and sedimentary rocks of various kinds, and of fragments of all sorts of rocks in the former with boundaries no less sharply defined, is to me also a very strong argument against the "melting down" hypothesis.

† Geology of the High Plateau of Utah, ch. iii.

‡ Geol. Mag. Dec. 3. vol. ii. p. 106. Nature, vol. xxxi. p. 444.

Further, the asserted passages between igneous and sedimentary rocks rest at present on evidence which, I have already stated, we are justified in putting out of court. They require confirmation, and we know that many instances, once confidently asserted, have broken down on strict examination*. Indeed, I may venture to assert that, so far as my experience goes, the difficulties at present existing either are due to obliteration of the original structure by subsequent mechanical or mineral change, or occur among the very earliest rocks of which we are cognizant; the latter are not only likely to have undergone such changes, but also may have been formed under circumstances which have never recurred in the history of the earth. These, for the present, I put on one side, hoping on a future occasion to return to them, and limit myself to the great body of rocks which all admit to have solidified from a state of fusion, and to those which (although field-evidence may be wanting) we may reasonably believe, through their close structural correspondence, to have been so formed.

So much controversy, however, has existed as to the origin of granite, that I shall venture a few additional remarks on this subject. To me it appears to a very large extent a dispute about the two sides of a shield. On the one hand, the phenomena exhibited by granite masses intrusive into other rocks, *i.e.* sharply defined junctions, contact-metamorphism, the sending off of dykes and veins which gradually assume the structure of normal felsites, perhaps even of rhyolites, justify us in asserting that granite cannot be separated from the other plutonic rocks such as syenite, diorite, and gabbro. At the same time it is true that there are abnormalities incompatible (so far as we know) with the idea of dry fusion, and that water is actually present in numerous minute cavities; but the same is true in some of the rocks above named. Further, I do not suppose that any geologist at the present day would assert that perfectly dry fusion is a common thing in nature, if, indeed, it ever exists. Clouds of steam are discharged from the craters of volcanoes and the surfaces of lava streams as they flow. The latter by parting thus with their water will cool in a manner more analogous to that of a furnace-product; had the same material solidified deep in the earth, a large portion of the water at any rate would not have been

* With regard to the alleged transitions from igneous to sedimentary rocks, Dr. Wadsworth, in his recent 'Lithological Studies' (a copy of which through the author's kindness reached me after the greater part of this address was written), uses language which, though severe, is not unjustifiable (p. 12). After dwelling on the numerous cases where the asserted evidence of transition has proved to be either negative or exactly opposed to the hypothesis, he continues:—"Practically, when the existence of these junctions has been shown, the observers who had previously denied their evidence have always said, 'That is not a typical locality; we were not quite sure about that place, but if you will go to such and such a locality,' indicating some new one, 'you will find an undoubted passage of sedimentary rock into eruptive forms.' When the new locality is also examined and the statements are found to be erroneous, another one is mentioned, and so on; until one must demand hereafter of these observers that they shall select some locality on which they shall be willing to fully and finally stake their pet hypothesis, and abide by the evidence."

disengaged, and thus crystallization, and previous fusion (if the rock has not always been molten) have taken place in the presence of water. Thus the controversy is either illogical, if restricted to granite, or merely a verbal one, if extended to other plutonic rocks. But some will assert that granite may justifiably be considered alone, because many cases exist in which a perfect passage can be traced from normal granite into normal gneiss. As regards this assertion, I repeat the remark already made, that these cases are less numerous than is supposed. I have examined a good many asserted cases of transitions from igneous to sedimentary rocks, and found that, as a rule, the distinction between the two rocks was well marked, and that the generalization was the result either of preconceived theory or of too hasty observation; further, that precisely similar difficulties exist with syenite and diorite, though the cases are less numerous, as the rocks seem not quite so common; lastly, that those cases which appear to favour the theory occur only in the case of rocks which there is good reason to believe are among the most ancient yet discovered. These, as I have said, I lay aside for the present. But in the case of the Palæozoic and later rocks it is only rarely, and under circumstances suggesting subsequent obliteration of the characteristic structure, that I see a difficulty in distinguishing between rocks of igneous and of non-igneous origin.

I shall not then dwell further on the question of the origin of an igneous rock, but I shall use the term to signify one that has solidified from a state of fusion, due to the existence of an elevated temperature, whether we might call this dry fusion or not. Further, in my classification, I shall draw no line of demarcation between igneous rocks of Tertiary and Post-Tertiary age and those of earlier date; the reasons for this I defer, and think myself justified in so doing, because it is one which logically would not arise in any independent study of petrology, but would be imported into it as the result of conclusions arrived at from other considerations not entering into my classification.

Theoretically, and probably also in practice, there are at least two well-marked physical conditions in which any rock of a definite chemical composition may occur, the hyaline and the holocrystalline. Is there an intermediate condition wherein the rock, though no longer vitreous, though exhibiting some differentiation of constituents, has not attained such complete individualization as to justify the use of the term holocrystalline? I do not allude to the interposition in the glass of a great number of microliths of individualized minerals, although this may offer obvious practical difficulties, nor do I refer to the size of the crystals making up the holocrystalline rock. I should deem the latter epithet properly applied, whether the character was readily observed with the unaided eye, or could only be seen under the microscope; but I speak of cases in which the material appears to have lost the usual property of a colloid, to have acquired, around innumerable centres, polarities in one or more directions, without its being possible to distinguish with precision what are the minerals into which it has segregated; where, in fact,

phenomena akin to those of tension or compression appear to have been permanently impressed upon the mass, only in a vast number of directions. This question also can best be considered in a separate excursus. Suffice it to say that, in the present state of our knowledge, it appears to me convenient to admit the existence of an intermediate division, to contain the rocks often called "cryptocrystalline" with some of the "microcrystalline," whatever may be the ultimate fate of the division. We will therefore assume that we may expect to find an igneous rock in either a holocrystalline, a hemicrystalline, or a hyaline condition, admitting that the middle term is perhaps rather incorrect as a symbol of facts and temporary in its existence. The relative size of the constituents in rocks, and their arrangements—such structures in short as are designated by terms such as porphyritic, spherulitic, fluidal—I shall at present regard as only varietal.

There is, however, one question of principle in nomenclature to which I must briefly advert. It is whether we should indicate distinctions of minor weight by conferring separate names, or by the use of qualifying adjectives—that it is to say, whether in our nomenclature we should direct the mind chiefly to specific or generic differences. The former is the habit in mineralogy, and it is in favour with some petrologists. While fully sensible of its advantage in conciseness, I believe it open to grave objection. Some questions of nomenclature, those, for instance, of priority, are of little value. It is comparatively unimportant, subject only to considerations of euphony and orthoepy, what we call a rock, so long as the name expresses as definitive an idea as the circumstances of the case permit; but it is a matter of great moment whether our nomenclature suggests or obscures relationships which exist in nature. Distinction is, indeed, necessary for clearness of thought, and is requisite as a first step in scientific comparison; but it is by comparison and recognition of relationships that all great advances in morphology and in philosophic reasoning are likely to be made; and it is, methinks, a matter of no small importance to keep clearly in view, in any system of nomenclature, the underlying affinities rather than the superficial dissimilarities.

Our nomenclature in petrology suffers in some parts, as I shall presently indicate, from a plethora, in others from a defect of names. A further difficulty exists in that there are not a few names which have been so vaguely and variously used, that it seems hopeless ever to render their meaning fixed or precise; these it would be better, in my opinion, to leave as admittedly vague terms, indicative of imperfect knowledge. So applied, they become valuable. Petrology needs what I may call "travellers' terms," to be employed as a naturalist would use trivial or generic names, when he either had failed in getting a good view of a creature or had not yet worked out the characteristics of a specimen. In this sense such terms as felstone, greenstone, even trap, are valuable. Aphanite, however, is not so good as compact greenstone, unless we can agree upon a perfectly definite meaning for it; and the same objection applies to

melaphyre, which, however, would be useful if admittedly left vague. Porphyry is admissible as a vague term, but objectionable in any system of classification, because of its diversity of applications in the past. Elvanite is a term wholly bad, because it suggests inaccurate ideas, by affixing a Cornish miner's trivial name, used even in that county in a very inclusive sense, to a rock which is world-wide in its distribution. Plutonic and volcanic also, though useful for rough divisional purposes and as general expressions, cannot for obvious reasons be used for exact classification. I mention these as examples, the list not being intended to be exhaustive.

As already intimated, I should not regard the conspicuous presence in a rock, whether crystalline or vitreous, of one or more minerals in crystals larger than others as justifying the use of anything more than an adjective; hence in dropping the term porphyry from our classification, I should continue to use the epithet *porphyritic* (notwithstanding obvious etymological objections); neither should I signalize the presence of macroscopic cavities, whether large or small, except by an epithet, or by the employment of a trivial name for general purposes of description.

If the above premises be admitted, it is evident that our system of classification must, so far as regards the igneous rocks (previously limited by definition), rest upon chemistry*. To a very large extent it will be also mineralogical; but we must not say wholly mineralogical, because that science will not enable us to determine the exact position of a hyaline rock, and, if alone regarded, may induce us to pay too much regard to minerals which can be shown to be the result of secondary actions after the first consolidation of the rock. Igneous rocks, we must remember, like any others, are liable to metamorphism; and we should try, as far as possible, to separate in our classification the latter from those which are comparatively unchanged. Now it is well known that, *cæteris paribus*, the more basic a rock the more readily it assumes a holocrystalline condition. Natural glasses are rare and limited in extent among the basic rocks, are comparatively common and well developed among the more acid, and probably are largely represented among ancient rocks, which, strictly speaking, cannot now be called vitreous.

Marked chemical and marked mineralogical differences should, then, be recognized primarily in any system of nomenclature. On the whole I am disposed to attach more weight to the former than to the latter, because sometimes a marked mineralogical difference, for example the substitution of hornblende for augite, may be the result of subsequent change, which, however, it may be difficult to substantiate. Of course, when such changes can be proved to have occurred, the rock should be removed from the category of *normal* igneous, to that of *metamorphic* igneous.

* In reality, of course, our classification deals with the aggregate history of the rock, its ontology as well as its morphology, if the phrases be permitted, because our limitation in using the epithet igneous, presumes an investigation into its relations with other rocks, an investigation into its *petrology* as well as into its *lithology*.

Our nomenclature, then, after the recognition of these essential distinctions, must further acknowledge the more accidental, viz., the physical condition of the rock, whether hyaline or not, the relation of its constituents, and the like. Many of these secondary distinctions I should prefer to indicate by adjectival affixes, reserving differences of names for marked differences in chemical constitution, and, after that, of crystalline condition. The latter, I grant, refers rather to a difference of environment than to a difference in essence; a holocrystalline, a hemicrystalline, and a hyaline rock of the same chemical composition have quite as near a relation one to another as the larva, pupa, and imago of an insect; but the marked difference in aspect and structure justify us, I think, in a nominal separation. The presence of an adventitious mineral not materially affecting the chemical composition, peculiarities of structure or the like, should, I think, be indicated by epithets.

The number of minerals, as is well known, which enter into the composition of igneous rocks frequently enough to entitle them to be called "rock-forming," is but small; for convenience they may be grouped as follows*.

I. *Oxides of Iron, &c.*

Magnetite, hæmatite, ilmenite, chromite (with spinel).

II. *Magnesia-iron Silicates.*

Olivine, enstatite (with hypersthene), augite and hornblende, biotite.

III. *Alumina-alkaline Silicates.*

Felspars (with nepheline and leucite), muscovite.

IV. *Free Silica.*

Quartz.

From this list such minerals as apatite, zircon, titanite, sodalite, nosean, are omitted, though occasionally some of them may be regarded as rock-constituents, because they do not appear to have any very important classificatory significance, and some are generally associated with certain of the above named. Garnet also is excluded, though occasionally an important rock-constituent, because, as it seems to me, we are not yet in a position to deal with it. If an original constituent, and not an accidental one, due in some way or other to contact-effects, I am disposed to regard it as a member of No. III.

The igneous rocks, then, as it appears to me, fall naturally into the following grouping, commencing with the most basic and using the existing nomenclature as far as possible.

The *Peridotite* group consists of olivine with some members of I. and commonly some representatives of II. Its simplest holocrystalline representative is *dunite*, essentially olivine and chromite. (I should apply the name to the rock whatever representative of Group I. were present.) The next marked variety is given by the

* I follow very nearly the classification proposed by Rosenbusch.

addition of an enstatitic mineral *. For this Dr. Wadsworth proposes the name *saxonite* †. Another marked variety adds augite or hornblende; to this we may apply the term *lherzolite* ‡, though hitherto it has been limited to one containing an augitic mineral, because I think that here the substitution of hornblende has no important significance. This group, then, consists of rocks containing little or no alkaline constituent, little lime or alumina, the last named often occurring in very small quantities, a considerable proportion of iron-oxide, and magnesia and silica in nearly equal proportions, the former generally slightly exceeding the latter, and each not far from 40 per cent. Hemicrystalline and vitreous representatives of these rocks are extremely rare. I have never met with one of either in my own experience, though I should expect them to occur. Thus no names have been proposed for them. They are largely represented in past time by the true serpentines §, their metamorphic representatives, into which they pass by insensible gradations; among these, I have suspected, though I cannot prove it, the presence of glassy representatives, which, however, are rare and local.

The *Picrite* group may be regarded as a transitional one, formed by the introduction of a small and variable amount of felspar, such as anorthite or labradorite; the amount of olivine is diminished; enstatite and a pyroxenic mineral, with biotite, become important constituents. The chemical composition, as might be expected, is variable, but the percentage of silica is slightly greater than in the last group, though generally not more than 45. Magnesia, though still one of the two dominant constituents, is present in an amount distinctly less than the silica, commonly from about 17 to 27 per cent. Alumina is always present, sometimes in considerable quantities, with alkaline constituents; but chrome and nickel, which are generally detected in the normal peridotites, are now often absent. These rocks, so far as we at present know, are generally ancient, and often more or less altered ‖; but I think the name

* I will use this term for brevity to include either enstatite, bronzite, or hypersthene, minerals very closely related, if not varieties of one species.

† Lithological Studies, pp. 84, 193.

‡ Dr. Wadsworth proposes (*loc. cit.* p. 193) to limit the term *lherzolite* to the variety with diallage, and call that with augite *buchnerite*, applying to a variety with diallage and without enstatite the name *eulysite*. I doubt, however, the possibility of separating the first and second. *Eulysite* also has hitherto been applied to a garnet-bearing peridotic rock.

§ I am, of course, well aware that this statement has been disputed, but have more than once given my reasons for it, so need not repeat them. On the principles of reasoning which I have endeavoured to establish above, I am unable to understand how the derivation of a true serpentine, *i. e.* that of which the Lizard serpentine is a type, from a peridotite, or the igneous nature of the latter rock can be doubted.

‖ The serpentinous rock of Duporth (Cornwall), for which the name Duporthite has been needlessly proposed, appears to be a member of the picrite group. Many of the picrites certainly hang on very closely to the dolerite group (described hereafter), and can be seen to graduate into representatives of it.

picrite preferable to that of *palæopicrite*, which has been given by many authors. To this group probably the eulysites of some authors (garnet-bearing peridotites) should be referred, and *limburgite* would represent the hyaline form. I am not aware that a hemicrystalline form has been recognized, certainly it has not been named.

As subgroups or intermediaries between this last group and the next great one, we may regard the *norites* or *hyperites*, composed chiefly of a plagioclase felspar (anorthite or labradorite), with an enstatitic mineral and perhaps a pyroxenic; the *corsites*, anorthite hornblende rocks (perhaps we might use *eucrite* for the anorthite augite); and the *troktolites*, containing the same felspar with olivine and but little of a pyroxenic mineral. It is perhaps well to retain these names, but it must be remembered that they have hardly a generic value. It may here be worth while to call attention to the fact that many of the so-called hypersthene rocks, *e. g.* the gabbros of Skye, and of Carrock Fell (Cumberland), either do not contain hypersthene, or have it only as a very rare accessory, while in others it is not more conspicuous than a pyroxenic constituent, so that there is no valid reason for calling them more than hypersthene (or enstatite) dolerites or gabbros.

We come then next in order to a most important group, that which contains, as constituents, a plagioclase felspar, commonly labradorite, a pyroxenic constituent, usually augite (or occasionally diallage), and often olivine *. To this group many names have been given, and various subdivisions of it have been proposed. Some authors extend it so far as to include rocks in which either nepheline or leucite replace the felspar, calling them respectively nepheline-dolerites, &c., or leucite-dolerites, &c.; some distinguish those in which olivine is present from those from which it is absent. For myself, while fully admitting the relationship of each of the former pair to the normal dolerites, and the frequent existence of intermediate forms, I think that the marked chemical differences (in the large percentage of alkalies) justify us in separating them from the felspar-dolerite and in retaining the old names, *nephelinite* and *leucitite*. Some, again, using geological age as a distinction, apply the name *diabase* to a rock if it is Pre-Tertiary, and *dolerite*, if of later age; this, of course I could not accept, but should propose to give the former name to dolerite in which marked alteration, subsequent to the original consolidation, has taken place. Others, again, apply the name *gabbro* to coarse-grained varieties in which the pyroxenic mineral is wholly or chiefly diallage. There is much convenience in the use of this term for a variety often so well marked in the field; but there is at present doubt as to the classificatory value of diallage, some authors of great weight regarding it as really an altered condition of augite. Provisionally, however, we may retain it, remembering that it may be logically indefensible. As,

* I shall, for brevity, not again refer to the presence of a member of Division I., because some oxide of iron, magnetite, hæmatite, or ilmenite is to be found in every rock, though usually more abundantly in the more basic.

however, many gabbros have undergone much alteration, the felspar being changed into a saussuritic mineral, the diallage into some form of hornblende, it would be well to restrict the term *euphotide* to these. Again some authors use the terms dolerite, anamesite, and basalt for rocks which, chemically identical, and all holocrystalline, differ in the coarseness or fineness of their grains, so that the last term is applied to a rock which either may be holocrystalline or may retain a glassy base. It would be convenient, then, to restrict the term *dolerite* to the holocrystalline variety, using the epithet coarse-grained or fine-grained as the case may be; to apply the name *anamesite* to the hemicrystalline varieties (very few and local, I suspect); and to include in the term *basalt* all that retain a glassy base, *i. e.* the magma-basalts and glass-basalts of some authors. It may be found convenient to use the name magma-basalt (as does Bořický) for those in the base of which the felspar remains unindividualized. The name *tachylyte* has been applied (as is well known) to varieties where almost the whole material remains in the form of glass, and the term may be conveniently retained, if we remember that it is only a marked variety of the glass-basalt division.

Two rather limited groups of uncertain position come next in order, the *phonolites* and the *tephrites*. The former group is essentially characterized by the presence of nepheline and of felspar, which is commonly, in part at least, orthoclase, the latter by leucite and felspar (more commonly plagioclase); but there are several accessories and many varieties, as may be seen from an examination of Bořický's divisions of the former group alone. It also is one whose nomenclature is in great confusion. Among the older members we have zirkon-syenite, elæolite-syenite, nepheline-syenite, foyaite, ditroite, miascite, while the one term phonolite covers all varieties, whether holocrystalline or not, among the more modern.

The group being, to a large extent, a transitional one, differing from that last in order by a higher percentage of silica and of alkalies, and a lower percentage of lime and magnesia, we can hardly hope to secure very marked type-forms; but perhaps the name foyaite might suffice as a specific term for the holocrystalline varieties; while in the case where the characteristic mineral is very distinctly the variety elæolite rather than nepheline (which does not appear to be the case with all foyaites), we might prefix the term elæolite. We should thus have as varieties elæolite-foyaite, nosean-foyaite, &c. It will, however, be a subject for consideration whether it may not be desirable, after the analogy of the groups which follow, to divide those in which a plagioclase felspar predominates, from those in which the felspar is chiefly orthoclase; but as my opportunities of studying this group have been rather limited, I will not venture an opinion on this point. Of the tephrite group I must speak yet more guardedly; for although I possess specimens, I have not had the opportunity of paying much attention to the rock. The name, however, is convenient to denote plagioclase-leucite rocks, and should be applied to rocks in which the former mineral predominates, and the percentage of silica is higher

than in the leucitite group and the forms intermediate between it and the dolerite group. An examination of a table of the chemical composition of minerals shows that with a high percentage of alumina compared with the silica, we shall obtain anorthite in rocks rich in lime and poor in alkalies; labradorite with a lower percentage of lime, and a moderate proportion of alkalies (chiefly soda); nepheline with a higher percentage of alkalies, soda still predominating; and leucite with an exceptionally high percentage of potash.

The next two groups contain a higher proportion of silica, rarely less and often more than 60 per cent. Normally they may be defined as felspar with hornblende, though in certain divisions augite more commonly replaces the latter; biotite is not unfrequent, sometimes dominant over the pyroxenic mineral; at times hypersthene is an important accessory, taking the place of the unisilicate olivine among the (more basic) dolerites. Although transitional forms may be found between these groups, it is convenient to designate the more typical representatives by different names; thus the orthoclase-hornblende group may be called, after the holocrystalline form, the *syenites*, the plagioclase-hornblende group, the *diorites*. Hemicrystalline and glassy forms of both are common, but it is by no means easy, especially in the case of the latter, to separate them without chemical analysis, though the character of any individualized felspar crystals is often a great help. I may remark, however, that not a few of the so-called hemicrystalline forms are in reality holocrystalline, though very fine-grained, and others can almost be proved to have assumed a hemicrystalline structure by secondary processes, so that in reality they should be placed in the metamorphic division; but leaving that distinction to await the results of further study, we may recognize the following divisions of the *syenite* group:—holocrystalline; orthoclase + hornblende = *syenite*; if mica replaces the hornblende wholly or to a marked extent, *mica-syenite*; if *augite* = *augite-syenite*. To the last rock, by no means a typical member of the group, as it contains much plagioclase felspar, the name *monzonite* has been given. The hemicrystalline division contains a considerable number of the rocks macroscopically grouped as felstones. By many authors they are called orthoclase-porphyries; but the name porphyry, as I have stated, being objectionable, and a binary term for a group being awkward, I should prefer to call them *felsites*. Then those in which orthoclase or any other mineral was conspicuously present might be called orthoclase-felsites, hornblende-felsites, mica-felsites, or the like. Hyaline forms are now becoming abundant, though commonly the glassy base contains a large number of individualized minerals. These are generally named *sanidine-trachytes*; but as the term *trachyte* is used like *felstone* for grouping in the field, its use in this more limited and strictly definite sense is objectionable, and, as before, the compound term is awkward. It is no part of my present purpose to attempt to coin new names, so I content myself with expressing a hope in this and like cases that a geological congress will some day invent and authorize one; till then I must

continue to use that which exists, though under protest. Wholly glassy forms doubtless exist, though probably not very abundantly; but it is sometimes difficult to distinguish these among the pitchstones and obsidians, of which the majority belong to rocks with a higher percentage of silica.

In the *diorite* group a considerable portion of the plagioclase felspar belongs to one of those which contain a higher proportion of silica than labradorite, though that felspar is often present, and some distinguish a subgroup the *labrador-diorites*. In this case, however, much care will be needed to see that we are not really dealing with a member of the *dolerite* group, where the augite, by paramorphic or other change, has been altered into hornblende. As in the case of the *syenites*, we have, then, in the holocrystalline division, *diorite*, *mica-diorite*, and *augite-diorite*, the last being of rare occurrence. For the hemicrystalline division there seems to be a general concurrence in favour of adopting the term *porphyrite*, which we can subdivide as in the case of felsite; and for the hyaline we have the term *andesite*, which division is separable into the *hornblende-andesites* and the *augite-andesites*, the latter mineral occurring more frequently is these than in the *porphyrites*. In these, and especially in the latter, hypersthene has recently been frequently detected in considerable quantities, so that its presence requires to be noted by a prefix. Mica is not unfrequent. It is evident that the *augite-andesites* form a link with the basalts, and the hyperstheneiferous *augite-andesites* approach the *norites*; to one or the other many of the rocks called melaphyres really belong. Wholly glassy forms no doubt exist, as in the last group.

As a small outlying group from the syenites we have the *minettes*, which may be regarded as extreme forms of the mica-syenites, being composed chiefly of orthoclase and mica (commonly biotite), and the *kersantites*, extreme forms of the mica-diorites. Of both groups hemicrystalline forms, as well as those with a glassy base, exist; but distinctive names have not generally been assigned to them. As a rule, they contain a slightly lower percentage of silica than the normal syenites and diorites. They occur also, so far as I know, in masses of very limited extent, mostly dykes and veins, and are commonly, though not universally, of Pre-Mesozoic age.

We arrive now at the concluding pair of groups, which differ from the last described in these respects:—quartz is present as an essential constituent, and not as an accessory; in the orthoclase group mica is much more common than hornblende; and muscovite, or a light-coloured mica of some kind, which has hitherto been rare even as an accessory, becomes sometimes an important constituent. As before, transitional forms between the two groups exist, and probably a plagioclase felspar is never wholly absent from the orthoclase group. That, however, may be defined, when holocrystalline, as essentially consisting of quartz + orthoclase + mica, and is the familiar *granite*. Some have proposed to restrict this name to those varieties where the mica is muscovite, and to call those with biotite by the name *granitite*; the name *pegmatite* is

useful for varieties exceedingly poor in muscovite. At present we are obliged to designate the hemicrystalline members *quartz-porphyry* or *quartz-felsite* (I would call these *elvanite,* were not the name so radically bad, or *eurite,* had not that term, in sympathy with its etymology, been used vaguely); here also we wait for a name*. Hyaline forms, as might be expected, are more common than ever; those in which individualized constituents (commonly microlithic felspars) abound are called indifferently *quartz-trachytes*, *liparites*, and *rhyolites*, though the last term is generally applied to more compact and so less rough (or less *trachytic*) varieties. The first term is open to the objection already stated; the second to this, that the rock abounds at many places besides the Lipari Islands; while the third perhaps indicates too distinctly the appearance of having once flowed. If, however, it were agreed to use trachytic as an adjective, and call *trachytic rhyolites* the rocks usually named *quartz-trachytes*, the difficulty would to some extent be avoided. At present the most glassy members of this and the next group receive the names of *pitchstone* and *obsidian*, the former name being applied to rocks with a resinous lustre, due probably to individualization of extremely minute microliths, and the latter to the most perfect glasses, which also have a more distinct conchoidal fracture, that of the pitchstones often being splintery.

In the second group the name *quartz-diorite* is commonly applied to the holocrystalline members, which may be defined as quartz + plagioclase + hornblende (biotite being here decidedly less common than in the other); but I think the name *tonalite* greatly preferable, for as this rock appears to be far less common than *granite*, it may be allowable to use the name of a locality where it occurs in a huge and very typical mass. For marked varieties we should have the names *mica-tonalite* and *augite-tonalite*, the latter probably being very rare. For the hemicrystalline division we have at present no other name than *quartz-porphyrite*; but for the hyaline division, corresponding with the *quartz-trachytes*, we have fortunately the name *dacite*. Of the most glassy varieties I have already spoken. It may be remarked that free quartz appears to be less common with the plagioclase felspars than with orthoclase, perhaps because albite contains a higher percentage of silica than orthoclase. Extremely glassy forms also may prove to be rarer in this case, because, as I am informed, a soda-glass is more liable to set up crystallization than a potash-glass.

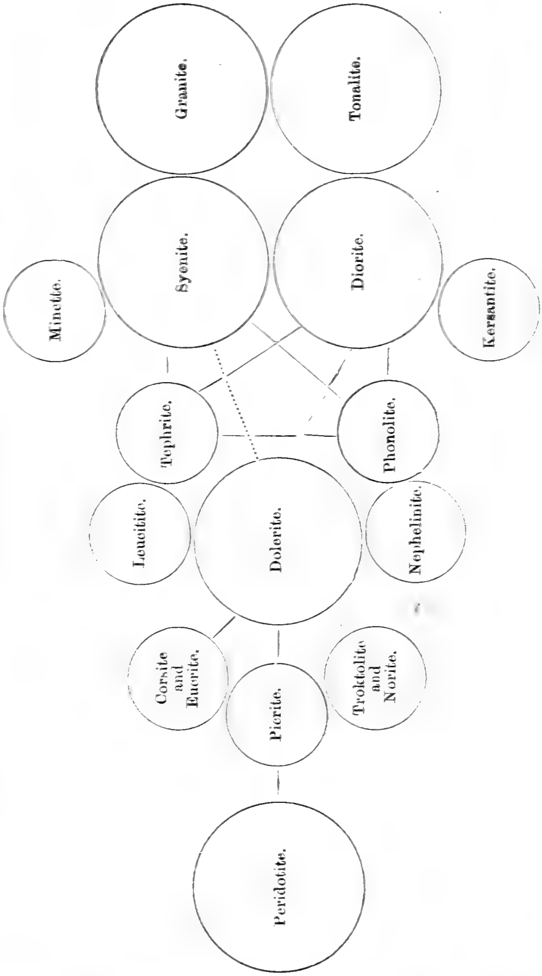
From the above remarks it will appear, not only that our nomenclature is at present in much confusion, due in part to the want of any definite principles, but also that the inherent difficulties are considerable, owing to the existence of transitional forms. At the same time I believe that there is sufficient predominance of what I

* *Granophyre* has been proposed by some distinguished German authors; but this term has been used in more than one sense. In fact, as will appear from the latter part of this address, I believe the subgroup will have to be rearranged, because its structure is often of secondary origin.

may call type-forms to justify us in the assumption of the existence of species for purposes of classification, and I trust that I have indicated a natural and logical principle on which to proceed. The relations, then, of the groups may be expressed graphically in the annexed diagram.

Diagrammatic Representation of the Affinities of the Principal Rock-Groups.

[NOTE.—The alliance of the Phonolite and Tephrite groups is much closer than can be represented in the diagram.]



In the above sketch of what appears to me a natural system of classification, I take no notice, as above stated, of the geological age of the rock, which is regarded as of primary importance by many continental investigators, who consider Pre-Tertiary igneous rocks always separable from those of later date. For this distinction I

have never been able to find any solid ground, and will briefly indicate the reasons why I venture to dissent from several eminent authorities. At the outset, we naturally feel some surprise that the commencement of the Tertiary period should coincide with so marked an epoch of change in the history of petrology, so that the igneous rocks, like the mammalia, should be *en pleine évolution* after the close of the Secondary period. But we may further ask, Was there any long pause, any universally definable limit, between the two periods? Did the curtain fall for an interval between two acts of the drama of life played on the world's stage? Granted that Tertiary can be sharply defined from Secondary in Britain, or even in parts of Enrope, can that line be drawn everywhere? Palæontologists, geologists in general, will, I think, accord in returning us a negative answer. Still, admitting the impossibility of adopting any very hard and fast line, there is yet a possibility that a certain "evolution" may exist among the inorganic products of the earth, and that the older may be distinguishable from the newer rocks. Let us then inquire how far this idea is in accordance with facts.

The older rocks, of course, are more likely to have undergone mineral changes during the vicissitudes of their longer history. The less stable minerals will have disappeared, and their constituents will be represented in more stable forms. Olivine will have been changed into serpentine and iron peroxide: augite and diallage into some form of hornblende, or all these will have been replaced by viridite or chloritic minerals: felspars will have been replaced by zeolites or other alteration-products; their materials may have been employed in the composition of tourmaline and epidote, and the like. If the rock has had a glassy matrix, this may have been devitrified. In short, an ancient rock, like a living creature, can hardly fail to exhibit signs of old age. Thus we naturally expect to find such rocks as serpentine and diabase among the older formations, and should hardly expect that a Pre-Cambrian or an Ordovician lava would be absolutely identical with one emitted during the latest geological epoch. Further, as we hold that the more coarsely crystalline rocks, especially when members of the more acid division, have solidified beneath the pressure of superincumbent rock-masses, we should expect such rocks as granite to be usually of ancient date, not because a modern granite may not exist underground, but because it has not yet been exposed to view by denudation. It must, however, be remembered that there seems no reason to doubt the Tertiary age of some of the granite of the Inner Hebrides; certain Alpine granites also seem to me to be most probably Post-Secondary; at any rate I have seen in the West-central Alps perfectly typical granite cutting Lower Cretaceous strata, and I know of no indications of disturbances in that region until the Tertiary period had begun. Tertiary granite is also said to exist in the island of Jamaica. Some of the Carboniferous basalts of Scotland are admitted to be undistinguishable from those of Miocene age; most of them only differ by reason of subsequent mineral change. Restore the rock (and that it can be restored admits, I think, of no reasonable doubt) to its original condition, and your diabase resumes its place in the ranks of the normal

dolerites. Notwithstanding what has been written of late, I cannot admit that some of the altered peridotites and the serpentines of the Apennines are other than intrusive, if not in Eocene, at any rate in the latest Cretaceous strata, and thus, as deep-seated intrusions, cannot be in any case older than the earliest part of the Tertiary. Yet these are undistinguishable in all essential characters from olivine rocks and serpentine, which would generally be regarded as Palæozoic or, in some cases, Mesozoic. At our last meeting Professor Judd told us of Tertiary peridotites, picrites, and gabbros in the Hebrides not to be distinguished from similar rocks of far earlier dates. Indeed some authors have been so impressed with their ancient aspect as to insist on classing these gabbros with the norites of the Upper Laurentian.

We find yet stronger instances of similarity among the andesites and rhyolites. Mr. Teall*, in his excellent papers on the Cheviot rocks, has shown that, except for alterations which can only be attributed to the effect of time, some of the porphyrites of that region are chemically and mineralogically undistinguishable from the hypersthеniferous andesites of Tertiary or yet more recent age. Mr. S. Allport has shown that the devitrified perlitic rock of the Wrekin, which is indubitably older than the Lingula Flags, and in all probability is one of the later Pre-Cambrian lavas, is as nearly as possible identical, chemically, mineralogically, and structurally (except for devitrification) with the perlitic obsidian of Hlinik, near Schemnitz, and corresponds very closely with another Post-Secondary obsidian from Hungary. The red felsite, which in North Wales is found below the base of the Cambrian series, exhibits in some localities a fluidal structure, and every indication of having once been a true glass, and is chemically identical with the above rock from Schemnitz; while several of the lavas of the Ordovician series in Wales, as has been pointed out by Mr. Rutley and myself, are, except in this one regard of devitrification, not to be distinguished chemically or microscopically from recent rhyolites, exhibiting fluidal or perlitic or spherulitic structures. I have never been able to satisfy myself as to the distinction, insisted on for some time, between propylites and andesites, and I find that this is now repudiated by some of the best American petrologists. In like manner there was no reason for coining the barbarous term *felsi-dolerite* for the reception of some of the lavas of the Lake-district. Chemically, the majority are typical andesites, a few are basalts rich in glass, very similar to those of Tertiary age, and there are no other differences than such as are produced by lapse of time. In short, after a fairly exhaustive study of "felstones" and "trachytes" I may say that I am unable to recognize any distinctions between the more ancient and the more modern, besides those due to subsequent change, and that it is no more possible to connect these with any single epoch in geology than grey hair in the human subject with any one year of life.

The strongest arguments in favour of the division have been derived from the "mica-traps," the nepheline and the leucite rocks,

* Geol. Mag, Dec. 2, vol. x.

all, it will be noted, rather rare and exceptional rocks. The first, it is true, for long time appeared to be universally of Palæozoic age, and in England it is only lately that (in Devonshire) they have been found to cut rocks so late as Carboniferous; but M. Barrois has described kersantites*, which, in his opinion, are certainly Post-Cretaceous, and most probably Post-Eocene. The majority of the nepheline rocks are Post-Secondary. I am not aware that any nepheline-basalts have as yet been identified prior to the Tertiary period, but although many phonolites also belong to the latter, representatives of this group of earlier date are by no means wanting. I will not press the case of those remarkable masses of nepheline rocks which break through Silurian limestones and so strangely interrupt the level plane of the St. Lawrence Valley in the district near Montreal, although the opinion of Canadian geologists is in favour of their antiquity, because I am not aware that there is any actual proof of their age; but I may remark that the nepheline-syenite, which one would naturally, from its appearance, class with the Pre-Tertiary representatives of this group, contains perfectly typical nepheline; while some of the phonolites closely resemble European phonolites of Tertiary age. For a like reason I abstain from quoting the Wolf Rock of Cornwall, and even the liebenerite-porphyries of the Fassa Thal, although I think that the latter cannot well be later than some part of the Mesozoic period. But in any case I am unable to recognize more than a varietal difference in the so-called elæolite-syenites, or any real distinction between the nepheline which occurs in the foyaite of Portugal, considered by Dr. Sheibner to belong to the more ancient eruptive series, and that in sundry rocks of Tertiary age.

Little can be made of the restriction to Post-Secondary rocks of such rare minerals as haüyne and nosean, or of tridymite, which is very possibly not an original constituent, and very easily overlooked. It is of no avail to quote such minerals as tourmaline, topaz, beryl, zoisite, andalusite, staurolite, cyanite, &c., as restricted only to Pre-Tertiary rocks, because there is no evidence that any are proper to igneous rocks, and most are distinctly minerals of metamorphic origin. Muscovite also will not, I think, avail much, as its identity and history are yet far from clear. The strongest point in favour of the classification by geologic age can undoubtedly be made with the leucite rocks, for there can be little doubt that all which have been described are comparatively modern. Further I am not aware of any good ground for suspecting that in any of the more ancient rocks which have been microscopically examined this mineral has once been present, but has been replaced by pseudomorphs. Still we must bear in mind that in this respect negative evidence is not of great value; for the mineral is an exceptional one, being peculiarly rich in potash, and typical leucite rocks are very rare—so rare that for some time no instance was known beyond the limit of Europe. The experience also of Messrs. Fouqué and Lévy appears to me to be significant. They melted together microcline and black mica, the composition of the mixture being $SiO_2=40$, $Al_2O_3=17$, $Fe_2O_3=8$,

* Recherches sur les terrains anciens des Asturies, &c. p. 160.

$MgO=21$, $K_2O=10$ (Total $=96$*): the composition of a leucitite poor in silica and rather exceptionally rich in magnesia, the result being that they obtained "après recuit, un culot crystallin composé de leucite, de peridot, de melilite, et de fer oxydulé, c'est-à-dire, une variété de leucitite à péridot." This interesting result appears to suggest that microcline may, under certain circumstances, be the representative of leucite, notwithstanding their different percentage of silica; or, to put it otherwise, that the magma which, under certain circumstances, may crystallize as leucite and olivine, with melilite (or with slight differences probably augite), may, under others, form microcline and biotite (potash-iron mica). It is also to be noted that these observers found that the leucite crystallized only at a high temperature; thus in making artificially a leucotephrite from a mixture representing one part of augite, four of labradorite, and eight of leucite, the leucite crystallized at a "rouge-blanc," the felspar at "rouge-cerise"†. Thus it seems to me unsafe, in the present state of our knowledge, to rely too much on negative evidence afforded us by this one exceptional mineral.

It appears, then, to me that this attempted classification of igneous rocks into an older and younger series, notwithstanding the authority and a few facts which can be quoted in its favour, not only is in itself improbable, but also is opposed to the general results of investigation, so that its retention will impede far more than it will facilitate progress.

The order of solidification of the more important rock-constituents presents us with some peculiarities worthy of notice. The separation of iron-oxide takes place at a very early period—probably in

* This may be modified so as to come nearer to 100, thus:—
$SiO_2=41{\cdot}0$, $Al_2O_3=17{\cdot}42$, $Fe_2O_3=8{\cdot}2$, $MgO=21{\cdot}52$, $K_2O=10{\cdot}25$, Total $=101{\cdot}39$.

† The experiments, indeed, of MM Fouqué and Lévy (described in their 'Synthèse des Minéraux et des Roches,' a work of the highest value to geologists) appear to me to be so suggestive as to the history and relationship of igneous rocks, that I present the results in a tabular form (it will be remembered that the experiments were made by "dry fusion").

(i) *Negative results.*

They have failed in obtaining artificially rocks containing free quartz, orthoclase, albite, white mica, black mica, and hornblende.

(ii) *Positive results.*

They have succeeded in obtaining artificially andesites and andesitic porphyrites, labradorites and labradoritic porphyrites, basalts and labradoritic melaphyres, nephelinites, leucitites, leucotephrite, and lherzolite.

(iii) *Results indicating relationship.*

(*a*) 10 parts of oligoclase with 1 of hornblende produced an augitic andesite; 4 parts of microcline with 4·8 of biotite produced the leucitite mentioned above. (*b*) Microcline with oligoclase, nepheline, and augite produced in each case a glass in which were oligoclase, nepheline, and augite, without any trace of a monoclinic felspar. (*c*) A rock composed of wernerite and hornblende produced a characteristic augitic labradorite with a little melilite.

Minerals, however, which they have failed to obtain as constituents in artificially produced rocks, have been separately formed by MM. Fouqué and Lévy, and other experimenters,—e. g orthoclase, albite, and a brown mica, generally after long exposure to a high temperature. Free quartz also has often been produced by the intervention of water. It will be observed from the above that, except, perhaps, in the case of lherzolite, they have chiefly succeeded, as might be expected, in producing examples of the less deep-seated igneous rocks.

all cases this group of minerals is the first to solidify; even in the thin sahlbands of tachylyte we note the cloudy agglomerations of dark dust, globulites or trichites, which indicate incipient differentiation. These often, when well marked, are surrounded by lighter zones, indicating that the segregatory process has continued after motion was arrested in the mass; but we may remark that, in the peridotite group, the presence of a large amount of magnesia appears to have been unfavourable to the complete separation of the iron-oxide, so that a large quantity has remained as an iron-silicate in such minerals as olivine, enstatite, &c. There is usually as much, sometimes more, iron in a peridotite than in a basalt; yet a slide of the latter exhibits many more granules of iron-oxide than the former. Olivine appears to consolidate at a high temperature; but in the rocks rich in magnesia the bisilicates of the enstatite group, and perhaps those of the pyroxenic, appear commonly to have crystallized before it, though the difference cannot have been very great, since these minerals occasionally include (as in the well-known bastite-rock of the Harz) granules of olivine. If, however, the constituents of felspar are present in any appreciable quantity, then the olivine is anterior in solidification to the above magnesian bisilicates; for in the picrite group they frequently include grains of it, as does a brownish mica which occurs occasionally. As a rule, the felspars, including nepheline and leucite, when their constituents are present in large quantities, appear to separate out at an early period; they are then generally anterior to the pyroxenic mineral, and, what is remarkable, the more basic (and in the case of the true felspars the more fusible varieties) separate out before the more acid, so that the remaining magma contains a higher percentage of silica than the separated minerals. In accordance with the same principle and as an extreme case, quartz usually solidifies last in order. We find, however, even in rocks of tolerably uniform structure, whether coarse or fine, not unfrequent anomalies, so that it is almost impossible to draw up a table of minerals in the order of their solidification; and when we study those which occur porphyritically, the difficulties become greater. The following table exhibits some of these anomalies:—

	Composition of Ground-mass *.	Minerals occurring porphyritically *.
Peridotite ...	Olivine	Enstatite, augite, hornblende, biotite.
Dolerite	Labradorite † + augite	Olivine, enstatite, augite, labradorite.
Syenite	Orthoclase + pyroxenic mineral (also biotite)	Same minerals.
Diorite	Plagioclase + pyroxenic mineral (also biotite)	Same minerals, but often the plagioclase is a more basic kind, with hypersthene.
Granite	Minerals of syenite + quartz......	Same minerals, but quartz only in hemicrystalline or glassy varieties.
Tonalite	Minerals of diorite + quartz	*Id.*

* Oxides of iron and spinel group omitted.
† Name used generically; may include anorthite.

An explanation of these anomalies does not at first sight appear hopeful; we may, however, notice:—

1. That the temperature of consolidation for a mineral out of a magma is not necessarily identical with that of the isolated mineral, as one substance acts as a flux upon another.

2. That the more anomalous results are presented by the rocks which appear to have cooled rather rapidly.

3. That the presence or absence of water greatly modifies the circumstances both of fusion and consolidation.

4. That Prof. Daubrée's experiments indicate that pressure and the presence of water are favourable to crystal-building.

For instance, in a granite or a tonalite it is obvious that the quartz has been the last mineral to consolidate, while in quartziferous felsites and porphyrites, in rhyolites and dacites (even in the most glassy varieties), it is not rare to find good-sized grains, even bipyramidal crystals of quartz, among the porphyritic minerals. In regard to this, it seems worthy of remark that, among minerals so occurring in the non-holocrystalline rocks, a distinction is observable, some being so perfectly developed that they seem as if they had consolidated out of the enclosing magma shortly before it solidified, while others appear to have been subsequently modified; the latter being more or less cracked, fragmentary, corroded at the exterior, and sometimes bordered by ferruginous and other minerals. These distinctions probably indicate difference of history. In the former case I should regard it possible that the molten matter, during its upward passage, had been arrested for a considerable time in a position where any further fall of temperature was practically prevented, and the contained water was unable to escape: then crystal-building would go on; possibly the development of quartz might be favoured by an increase of the pressure * from the masses welling up behind. When the resistance in front is overcome, the fluid mass passes upwards and outwards, its temperature falling and its water escaping, so that further crystallization is impeded, and the mass assumes a hyaline or, at any rate, hemicrystalline condition.

The fracture of included minerals may be explained by strains set up during the motion of the enclosing magma as it approaches the condition of a solid body, while the exterior corrosion probably indicates that some local rise of temperature, or increase either in pressure or in the quantity of water, has affected the stability of the molecules in the crystal. It must be remembered that, during the intermittent upward progress of a lava-stream, its outer parts, by contact with cooler rock, may at times lose enough heat to allow of the formation of crystals during a pause (for I think that the constant shearing of the molecules in a moving mass would be unfavourable to the development of crystals of any size); but that when the mass again moves onward, the more solid crystalliferous crust may be carried into the interior of the mass, where the temperature has remained higher and its environment is different. It

* Prof. Daubrée's experiments show that pressure and water are very favourable to the development of quartz-crystals.

is not impossible that some of the peculiar cases of zonal structure in crystals may be due to changes of position, sometimes slight, during the process of formation. For instance, I think it extremely probable that the zones of albite enclosing the large orthoclase crystals in the "porphyroid" of Mairus in the Ardennes (I have no doubt this rock is of igneous origin) are the records of two phases in its history. In this way also very possibly the enclosure of hornblende by augite crystals, or, *vice versâ,* of nepheline by sodalite, &c., may be explained.

Definite pressure also during the process of crystal-building cannot fail to produce a marked effect. It may, I think, be taken as an axiom that, *cæteris paribus*, a molten mass under pressure will crystallize more readily than one not so affected. It is very possible that the devitrification of many of the ancient volcanic glasses has been largely due to the pressure which they have undergone from being buried deep below superincumbent strata. Molecular movement within limits can take place in many substances long before they cease to be solid, as is indicated, among other things, both by the ordinary devitrification of glass and by Prof. Daubrée's special experiments; and the mere fact that, in most cases, the specific gravity of a substance is higher in a crystalline than when in a colloid state, indicates the probable result of the application of pressure. But on the present occasion I shall as far as possible avoid what may be called subsequent metamorphosis, and confine myself mainly to structures which are due to the application of a force definite in direction during the process of crystallization.

1. Crystals, already formed, will be arranged with their longer axes in the direction of a tension, or at right angles to a pressure. This, as every one knows, is the explanation of flow-structure in microliths, and it is sometimes exemplified in the case of larger crystals.

2. Crystals, when forming, if exposed to a tension or pressure, will develope with their longer diameters in the direction of the tension, or at right angles to the pressure. This is especially well exhibited by platy minerals, such as mica and diallage. The foliated aspect of granites and gabbros near to their junction with a level surface of stratified rock has often been noticed; but as I observe that in the newly awakened enthusiasm for subsequent pressure as an agent in modifying rock-structures there is some danger of these being overlooked, I shall venture to recall a few from my own experience. I have often noticed that a mass of granite intrusive into a bedded rock has, for a depth of several inches, its mica-plates parallel with the surface of junction, and without the slightest sign of crushing. The most remarkable instance which I have ever seen was in the neighbourhood of Bergen; there a vein of granite, rather more than a foot thick, threw off a band some three inches wide into a transverse fracture in the schist. It was obvious that the angles of the latter rock, one being about 60°, the other about 120°, would offer resistances definite in direction to the viscid mass of the granite. Accordingly the plates of mica in the latter (as usual, not numerous) were arranged perpendicularly to the normals to the

surface of the schist; so that they resembled little fish which were turning aside from the main stream to swim up the branch. I have already described to this Society* cases of foliation developed in masses of gabbro in the neighbourhood of a junction with bedded rock, and one yet more remarkable where a vein which cut a mass of serpentine and had forced its way between two layers of a large included fragment of bedded rock, preserved its ordinary structure so long as it remained in the former, but became foliated when it was nipped, as between two boards, by the latter. I have also seen in a trapezium-shaped intrusive tongue of gabbro, the diallage parallel with each of the three sides exposed to view. There is, however, a marked difference between the foliation in these cases and that presented by rocks ordinarily called metamorphic. In the former the structure is generally less conspicuous under the microscope, and the crystalline constituents present the same characteristics of external form as in the ordinary igneous rock; but in the latter (whatever may have been the cause of the foliation—crushing of a rock already consolidated, or mineral change in a rock originally of fragmental structure) there is a marked difference.

The process of crystallization is the disturbance of equilibrium among the constituent molecules; that which was homogeneous is so no longer. The formation of large crystals appears to be analogous to that of small, and to be only a question of time. When we find a rock full of minute crystals, we may conclude that by a too rapid fall of temperature, freedom of motion was impeded and the separate crystallites were prevented from uniting. In this consideration we have to bear in mind the following facts, as stated above:—

(*a*) That a hyaline condition is rare and local among the more basic rocks.

(*b*) That in the majority of cases the more basic minerals separate first, so that the residue is rendered more acid, and thus, under changed circumstances, may more readily assume a hyaline condition (and so impede movement) than the original homogeneous magma would have done.

(*c*) That the minerals first formed will be the most perfectly developed; when two minerals are both ill developed, or sometimes one, sometimes the other, developed at its fellow's expense, the crystallization-point for the two is probably, *cæteris paribus*, nearly identical.

(*d*) That the fusion of an igneous rock is not "dry fusion," but fusion in the presence of water; and the same is true of crystallization, though the free discharge of water from volcanoes may bring the cases of certain lavas nearer to that of "dry solidification." This may be the cause of the unusual abundance of tachylyte in some of the Hawaiian volcanoes, as these discharge little steam from their molten but ebullient surface.

(*e*) That pressure modifies the circumstances of crystallization.

* Quart. Journ. Geol. Soc. vol. xxxiii. p. 893.

It may also be important as preventing dissociation, especially of water.

Let us now examine the mode of crystal-building in a volcanic glass, putting aside for the present the consideration of the crystals which occur porphyritically; because, as will be shown, there is no reason to associate their formation with this last stage of consolidation. A volcanic glass, when molten, may be either homogeneous throughout or not homogeneous. The former might produce a homogeneous solid, of which a piece of window-glass would be a perfect type; the latter a glass streaky from the occurrence of different substances, like various slags and very many glassy lavas. This is obviously due to the imperfect mixture of two materials (how mixed, matters not for our present purpose) of slightly different chemical composition, the masses of which during motion are drawn or "teazed" out into shreds.

Considering for a while the former case only, we see that the molten mass may solidify without marked separation of any of its chemical constituents, though this is rare. Commonly, numerous microliths are formed, and the history of these, if traced, throws much light on the process of crystal-building. For this purpose no better examples can be found than some of the well-known pitchstones of Arran. On examining a slide from one of these with an objective of low power, we see that the clear glass of the rock appears full of a minute spicular dust; on applying a higher power (say $\frac{1}{4}''$ objective) the particles of this dust are seen to be very small pale-green belonites, disseminated pretty uniformly and without orientation. Taking another slide, we perceive a number of larger belonites, and in parts of the same or in a third slide we find curiously tufted groups of the belonites, or aggregations of the smaller on the larger, like miniature spruce-fir trees.

Now each one of these—larger belonites, tufted groups of all kinds—will be surrounded by a lacuna of perfectly clear glass, while beyond that, there will be interspaces crowded, as above, with the spicules. Moreover a closer examination of the larger belonites will often show that they are compound in structure, built up by the laying side by side of the spicules; and further that in the fir-tree-like groups the branches, where they inosculate with the stem (to use a simile), sometimes make with it at first a comparatively small angle, and then stretch out more nearly at right angles, exactly as we see the young branches start at an acute angle with the upper part of a fir-stem, but afterwards drawn down by the increasing weight of the bough (a botanical fact of which I may remark, by the way, many artists take no note). It appears, then, pretty clear that either the increasing viscosity of the surrounding material, or the resistance of the tufts to which they were already attached, prevented these spicules from being incorporated into the main stem. Why in parts of the rock we have a uniform distribution of the spicules, and why in others they are able to aggregate as above, we cannot say; but probably it is due to some very slight irregularity—an almost infinitesimal difference might suffice—in the

composition of the rock. Some slides, however, illustrate another form of disturbance of equilibrium: crystals of quartz or felspar are imbedded in the rock, and on these the larger belonites have, as it were, grown, in accordance with a well-known law of crystal-building, that a mechanical disturbance of equilibrium is favourable to it, and every crystallite seeks its *ποῦ στῶ*.

Let us now proceed to the igneous rocks which are comprehended in the general term "trachytes;" rocks which still retain a glassy base, but have it crowded with microliths; in which also there is commonly a slightly lower percentage of silica than in such glassy forms as pitchstone and obsidian. Here we find crystallites of felspar largely developed, together with granules of augite, hornblende, and magnetite; these occasionally are so far associated as to afford instances of twinning, and they vary notably in size. In these rocks we are presented with a stage of crystal-building somewhat analogous to that just described, though taking place in a rock of slightly different composition. This microlithic structure appears to me to indicate that temperature (as in the former case) was changing rather rapidly, and crystal-building was arrested before it had progressed beyond one or two of its earlier stages. Hence I fully expect that it will be restricted to rocks which have either been emitted as lavas or, if intrusive, have solidified not far from the surface of the ground, that is, under circumstances which have allowed of comparatively rapid cooling and perhaps the free evaporation of water.

Let us now for a moment turn our attention to the larger crystals of quartz, felspar (and, in some more basic examples, nepheline and leucite), biotite, augite, and hornblende, which we find in porphyritic varieties of these rocks. These are not seldom found to have incorporated into themselves portions of the ground-mass or microliths of other minerals such as occur in the rock, which have been forced to obey the law of crystallization of their captor, and to arrange themselves conformably to it. Instances are too common to require enumeration. I interpret this to mean that the magma was maintained for a considerable time at the temperature requisite for the separation of some particular mineral, and only slightly below that at which some other mineral, present in a very much smaller quantity, had solidified. For instance, in the case of magnetite and leucite, the latter mineral begins to form in a magma in which scattered granules of the former have appeared. First, probably, there is a general development of microlithic leucites; next, owing to a slight non-uniformity of conditions, certain of these act as centres of attraction. The first tendency will be for the leucite microliths to aggregate and, in so doing, to exclude the magnetite, if it be only sparingly present; but after a while the nucleus becomes larger, the magma possibly slightly more viscous. Motion is not quite so free, and the converging microliths of leucite bring with them granules of magnetite, and, it may be, the enlargement of the nucleus (as mentioned above) facilitates crystal-formation; hence the granular magnetite is included in the crystal. (It must be remembered that when one

mineral is in the act of crystallizing and the other has crystallized, the latter is inert while the former is active.) It may also happen that in this crystal-building the attached microliths are now diverted in this way, now in that; thus twin-building of various kinds will result, and I should expect that this twinning might be more perfectly developed by molecular rearrangement after the crystal had formed, but while it was still plastic.

If this process of aggregation of one or more minerals be carried on to a considerable extent, the residual magma will obviously differ much from the original. At last this also may begin to crystallize. Then, if the fall of temperature, or the change of conditions be very slow, we shall have a coarsely crystalline mass enclosing the earlier developed crystals; but if the change is more rapid, one more finely crystalline will be produced. If the magma contain the constituents of minerals, of which any one (under the circumstances) crystallizes at a markedly higher temperature than the rest, we may expect perfect crystals of that to occur; if not we shall find that the minerals, though thoroughly crystalline in structure, are very imperfect in their external form.

In the case of slow consolidation it is obvious that if we suppose at different points in the mass the existence of centres of attraction of any kind, acting uniformly in every direction, the microliths as they form will be aggregated around them with a radial structure and thus will form spherulites. On this structure I have some further remarks to make, in relation to vitreous rocks, in which it is far more common; but I may point out here that the curious orbicular diorite may be thus explained. In these globular masses we can generally see a more or less indistinct nucleus, then follows a series of subspherical bands of anorthite and hornblende, the former predominating. The process, then, appears to be as follows:—The two minerals have crystallized almost simultaneously, the felspar having had very slightly the advantage. The nucleus, possibly only in consequence of the accidental presence of a slight excess of anorthite, acts as a centre of attraction, and anorthite from the parts of the magma in immediate continuity separates out and collects radially upon the existing nucleus. But after this segregation of the felspathic constituents from the magma has gone on for a certain time, there is a zone of it in which is a residual excess of the hornblendic constituents, so that circumstances now admit of the formation of the latter mineral; and thus a zone of it is built up, until again the inequality is more than redressed, and the formation of anorthite recommences. But this will not go on indefinitely; for general crystallization of a non-radial character will have been set up in the mass, so that at last molecular motion becomes impossible. The construction of spheroids ceases, and they are enclosed in an ordinary diorite. I notice that where the boundary of the spheroid is the most sharply defined, the outer ring is a thin one and is hornblende, as it should be with the mineral second in order of formation.

Leaving, then, for a moment, certain structural peculiarities, such

as spherulites, let us see how far we can connect those which we commonly meet with in igneous rocks.

Commencing with the hyaline stage (omitting minerals of anterior consolidation, and restricting our remarks to the rocks containing a fair proportion of felspar), we seem able to trace the following order of phenomena in rocks which do not remain in a condition so vitreous as the tachylytes, pitchstones, and obsidians:—

A. (1) Formation of a large number of felspar microliths, so that these become the most conspicuous objects in the ground-mass, in which, however, more or less glass usually remains. This gives the *trachytoidal structure* of many authors, and indicates a comparatively rapid fall of temperature, so that crystal-building is arrested at a rather early stage.

(2) Further development of the felspars, until their chemical constituents are wholly, or almost wholly, removed from the magma, followed by crystallization of the residue. This is the *ophitic structure* of authors, most perfectly developed when the residue has the composition of a pyroxenic mineral and itself crystallizes rather coarsely—a structure, I think, indicative of more gradual cooling, but still under no great amount of constraint. Not usual in the more acid rocks.

B. (1) Structure minute; but a glassy base is not distinguishable. Want of definiteness of external crystalline form, as though sometimes the separation of adjacent minerals had not been absolutely perfect, or an irregularity of boundary, as though crystallization had been simultaneous. Occasionally there is some approach to a coordination of structure, a more or less imperfect micrographic or spherulitic arrangement being visible. This is the *petrosiliceous structure* of authors, indicative, I believe, of constrained consolidation.

(2) Generally a coarser structure than the last. The separation of the minerals is more complete, and the felspars tend to have rectilinear boundaries. The *microgranulitic structure* of authors, which perhaps ultimately may be in great part classed with the next one, the remainder belonging to the first, and both belonging chiefly to the less basic rocks.

(3) Fairly coarse felspars, usually well-defined externally, especially in the more acid varieties, the *granitoid structure* of authors, especially characteristic of granites, tonalites, most syenites and diorites, and gabbros.

This last method of crystallization seems to belong to very deep-seated rocks, where consolidation has taken place under great pressure and in the presence of confined water-vapour; certain cases of (2), and perhaps some of (1), indicate the same process carried on more rapidly, and so occur frequently in vein-granites and intrusive felstones. The first, or *petrosiliceous* type, however, requires much discussion, and with some remarks on questions relating to this, I must conclude this already too lengthy address.

For many years the subject of the minuter crystal-building has been present to my thoughts, although the pressure of what I may

call larger questions has prevented me from devoting to it much of the time which I can secure from daily duties. It was a question to which my work in Charnwood and North Wales obliged me to pay attention, and I may mention that it is now seven years since I published a paper in the 'Geological Magazine' which dealt with the possible mode of formation of some spherulitic rocks in Arran. This will, I hope, be my excuse for putting before you some of the results of my own work, without direct reference to what others may have written on the subject. The question propounded to us by the study of this class of rocks in the field is practically this: Has the petrosiliceous, the spherulitic, the micrographic structure been produced during the original cooling of the rock, or has it been subsequently brought about? and if it has been produced at either time, is there any hope of distinguishing what I may call *original* from *secondary* devitrification? Besides studying a large number of natural rocks, I have examined some artificial glasses in the hope of obtaining some help from them.

I have to acknowledge with gratitude the assistance which I have received, both in information and by the gift of specimens, from Professor Judd, Mr. J. A. Phillips, Messrs. Osler, Mr. F. Claudet, and Mr. Frederick Siemens, of Dresden. To the last two I can hardly adequately express my thanks. Each, from the funds of his practical experience, gave me much information; each made me a liberal gift of specimens, Mr. Siemens even having some specially prepared for me. I may add that in the time at my disposal since these reached me, it has been impossible to do full justice to the many interesting questions to which they give rise; but I hope to make them the subject of further study.

Specimens of artificial glasses vary considerably in composition. The following are analyses (furnished me by M. Claudet) of flint-glass (I. and II.) and a (French) bottle-glass III. *

* M. Pelouze also, in his article *Sur le Verre*, Compt. Rend. lxiv. p. 53, gives the following analyses:—

Ordinary Glass.

SiO_2	77·04	73·05	77·80
CaO	7·41	15·16	12·50
Na_2O	15·51	11·79	9·70
	99·96	100·00	100·00

Alumina glass.
S. G. 2·380.

SiO_2	75·00
Al_2O_3	7·60
Na_2O	17·40
	100·00

Magnesia glass.
(Easily devitrified.)

SiO_2	68·9	65·7
MgO	14·9	12·0
CaO	...	7·3
Na_2O	16·2	15·0
	100·0	100·0

	I.	II.
SiO_2	64·70	69·65
Al_2O_3	3·50	1·82
CaO	12·00	13·31
Na_2O	19·80	15·22
	100·00	100·00

	III.
SiO_2	53·55
Al_2O_3	6·01
Fe_2O_3	5·74
CaO	29·22
K_2O	5·48
	100·00

In flint-glass the percentage of silica is often higher, that of alumina lower, and those of lime and soda more nearly equal than in (I.). In fact, we might take as an approximate composition of a typical flint-glass about 70 per cent. of silica and about 27 per cent. of lime and soda, in nearly equal proportions, the residue consisting of alumina, iron, manganese, &c. The presence of alumina, as is well known, renders the glass less fusible. Hence, in order to obtain devitrified specimens, Mr. Claudet was in the habit of sprinkling a little clay on the residual glass in a pot. (This, I think, acted mechanically as well as chemically, as probably it was not wholly melted.) Compound silicates also, he informs me, were more fusible than simple. In the comparative study of artificial glasses and of igneous rocks there are, however, two obvious difficulties—one, that the former, as indicated above, contain a much larger percentage of lime and of an alkali than we find in obsidians, pitchstones, or rhyolites, and that in regard to them we are dealing with dry fusion and dry solidification (Mr. Siemens informs me that it is an important matter to allow the "metal" to boil for a considerable time, *i. e.* to eliminate from it vapours and gases). As I had been informed that Messrs. Siemens were making bottle-glass from "granulite" or granite, I had great hopes of obtaining from them an artificially produced obsidian, and thus being enabled to study the devitrification of a substance chemically identical with a natural rock. This, I regret to say, is not quite the case. Their staple material is a granite or granulite, of which analyses are given below*, but a certain quantity of calcium fluoride and sodium chloride or sulphate are added. I was not informed of the exact amount; Mr. Siemens says it is done rather roughly, but "so as to make a good alkaline glass." Hence, even in this glass, we have more lime and alkali, as well as less magnesia, than we should find in such a rock as an andesite,

	*I. Light-coloured variety.	II. Dark-coloured variety.
SiO_2	69·30	60·90
Al_2O_3	17·70	19·10
Fe_2O_3	1·10	3·10
CaO	1·60	2·90
MgO	0·13	0·80
K_2O	3·45	4·10
Na_2O	5·20	5·53
Diff.	1·25	3·27

Difference contains H F, MnO, &c.

with which probably the silica and alumina percentages would more nearly correspond. Nevertheless, though this fact obliges me to hesitate at present as to the identification of the minerals formed during devitrification, these specimens have proved of great assistance*.

It will be convenient to describe very briefly the results of my examination of the various glass specimens referred to above, before indicating their bearing on the devitrification-structures of natural rocks.

In ordinary window-glass two types of crystals appear to be developed †. One consists of long acicular prisms of a clear mineral with a satiny lustre, like that of pectolite. These form spherulites (sometimes more than an inch in diameter in the body of the glass), but they also, as we might expect, form a more or less mamillated layer, starting from the exterior portion of the mass, especially where in contact with the sides of the pot. Both are composed of thickly crowded tufts of acicular or hair-like microliths, exactly like the growth of microcrystalline quartz which we can study in the chalcedonic linings of cavities in rocks. Sometimes they form radiate hemispheres, the plane face being the surface of the glass, the centre not seldom a little speck, which appears to have been one of the clay granules mentioned above. The second type is a mineral of a less satiny lustre and apparently not quite without colour, the larger aggregates having a faint ochreous-grey tint. Its habit of crystallization appears to be entirely different. Commencing with an elongated flattish prism, smaller prisms attach themselves to the sides at angles of about 60°, and to these in like way others are added. Occasionally the *rachis*, as I may term it, of the leaf becomes curved. These, again, combine into stellate six-rayed forms, reminding us of the well-known snow crystals, and develope into flattish hexagons like those figured by Vogelsang in the eighth and ninth plates of his work 'Die Crystalliten,' except that the outer boundary appears sharper than in those on the latter plate. A remarkable twinning now takes place, two composite crystals placing themselves at angles of 60° with the plane of the first plate, so that a vertical section would give us a six-rayed star. This process continues, but with a certain dominance of crystals lying in the original direction, so that its result is an aggregated mass of somewhat flattened forms, the longer diameter of which sometimes measures nearly an inch. At the ends it is rather concave, and its sides still retain a somewhat hexagonal shape. I may give a general idea of the appearance by comparing one of these to a ball of cotton

* I am, of course, aware of the glass formed from melting basalt; but on account of the rarity of glasses and structures suggestive of "devitrification" among the more basic rocks, I have not thought it worth while to spend much time over them.

† Mr. Claudet informs me that these spherulites were produced by stopping all the orifices of a furnace, and allowing it to become cool very slowly, the time occupied before the cooling was completed and the pots were withdrawn being from 8 to 10 days.

as ordinarily sold, if its sides were compressed by its being placed in a hexagonal box.

Both of the above crystalline aggregates appear to be sharply separated from the enclosing glass, which, I may remark, is often cracked for some little distance round them, as though by strain in subsequent cooling. Although the latter microliths appear to form tufted and sometimes spherulitic masses, like the former, by the crowding of the branch-like forms, so that they are compressed together like the twigs in a broom, yet I am disposed to regard the two as distinct varieties, if not distinct minerals. Probably, however, the difference in chemical composition is but slight. Their occurrence, often in the middle of a mass of perfectly homogeneous glass, leads one to suspect that they differ but little from it in composition, and are crystals of some lime-soda silicate, chemically as nearly as possible identical with the glass*. So far as I can at present ascertain, each is a monoclinic mineral.

Mr. F. Siemens sent me a specimen of "granulite glass" containing spherulites, taken "out of an old tank-furnace cooled down slowly with about 1000 cwt. of glass in it." The fragment is of irregular form, about $5'' \times 3'' \times 2''$, of a rich resin-brown glass, containing several spherulites beautifully developed, most of them about 1″ diameter, sometimes a little more; they exhibit a radial structure, with one distinctly zonal in the exterior part, forming a kind of "rind" about ·2″ thick. The inner part is of a pale yellowish-grey colour and has a slightly unctuous lustre; the outer has a pinker tinge and deader lustre; but the outermost zone, perhaps $\frac{1}{25}$th inch thick, more nearly resembles the interior. When examined under the microscope these spherulites are not very translucent, of a dusty grey colour and rather earthy aspect; the radial structure is rather irregular, the spherulite being apparently composed of a matted mass of rather curved acicular microliths; the zones are indicated by darker bands and there are some interesting minor peculiarities on which I must not dwell, except to say that beyond the spherulite is a very thin fringe of minute colourless crystallites. This mineral is probably an aluminous silicate, and resembles that in some spherulites which I have seen in obsidians and pitchstones; perhaps it is an impure microlithic oligoclase.

In all these specimens, described above, the various crystallites have formed during the cooling of the mass from a molten condition,

* Mr. Claudet tells me that some years since, he analyzed a glass and one of the enclosures, and found no substantial difference between them. I may add that Vom Rath's analyses of a pitchstone and a spherulite from Antisana (Andes) give but little difference. Dumas's analyses of a glass and its crystallized inclusion, however, show a decided difference:—

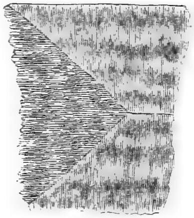
	Vitreous part.	Crystallized part.
SiO_2	64·70	68·20
Al_2O_3	3·50	4·90
CaO	12·00	12·00
Na_2O	19·80	14·90
	100·00	100·00

and thus illustrate what we may term *primary* devitrification. It represents a segregation of certain crystalline minerals from the body of the glass, which, however, undergoes no change whatever that is visible to the eye in the other part, the free ends of the microliths being bounded by a true glass, apparently identical with that in other parts of the mass. I now turn to some examples illustrative of changes produced by the action of heat upon specimens which have once been perfect glasses. The first, given me by Mr. F. Claudet, is one of great interest. It consists of a number of sheets of window-glass, which, when lying one on another, were exposed to great heat in the noted conflagration at Hamburg, and partially fused, so that they now form an almost solid mass about $\frac{3}{4}$ inch in thickness, with thin alternating bands of opaque-white and of clear glass, not unlike a banded rhyolite. A closer examination shows that, except at top and bottom, each white band is more or less double, half belonging to the underpart of one sheet, and half to the upper part of that in contact with it. Each is composed of a tufted growth of very minute acicular crystals of a pale brownish-grey colour. Usually their close approximation compels them to exhibit a brush-like structure; but occasionally where there are slight interruptions, we have more or less perfect half-spherulites, and in a few cases where the fusion of the surface appears to have been complete, we have a perfect spherulite, whose equatorial plane represents the former junction-faces. As the glass has not been completely melted, it seems probable that the spherulites are due to a crystallization of, not from, its material, and they clearly originated at the surface of the sheets.

A specimen, prepared for me by Mr. F. Siemens, further illustrates this. A group of four pint bottles of different-tinted granulite glass was exposed for twenty-four hours to a temperature of about 600° C. The heat has not sufficed to fuse the bottles, but they have been completely softened, have fallen together and become welded into an irregular flat cake, though the necks, lips, even the letters stamped on the bottles, can be readily distinguished. We have thus had about the same approach to fusion as in the former case. Here, too, a fracture through one of the bottles shows at either surface a white skin about $\frac{1}{25}$th inch thick, duplicated as before, where two surfaces have been welded together; but between these, in the clear glass, are numerous small spherulites from $\frac{1}{20}$th to $\frac{1}{10}$th of an inch in diameter. Here, again, one would imagine the chemical differences between the crystalline bodies and the glass must be extremely slight. The mineral has a similar aspect with, and is probably the same as, that in the larger spherulites described in the slowly cooled mass of granulite glass.

I am indebted to Mr. F. W. Rudler for a specimen of great interest. This is a fragment of a plate of glass, about 1·1 inch thick, devitrified by exposure in a crucible to a bright red heat for three weeks. A slide cut from it exhibits many points of interest on which I have not time to dwell; but the following have a special bearing on the question before us. So far as I can ascertain, there

is no residual glass; a fair quantity of an earthy dust, and sundry globulites have formed, also a number of minute belonites; but the dominant structure consists of crowded "brushes" of an acicular mineral with a general resemblance to that of the first type described above. The most interesting point, however, is that the fragment has three external faces, parts of the front, back, and an end of the plate; the acicular microlithic aggregates grow out from each of them until they meet, where a sharp divisional line is formed, visible even to the unaided eye, clearly indicating that the crystallites started simultaneously from each exterior face, and grew inwards till they met. The structure is roughly represented in the annexed diagram. Here, as the whole glass is devitrified, the dominant crystallites must be nearly identical in composition with it.



Section of a fragment of devitrified glass.

In concluding this subject, I must recall to your memory the most important experiments of M. Daubrée on common glass. These, however, were performed in closed tubes in the presence of water (about one third of the weight of the glass)*. Here the composition of the glass was considerably altered, quartz crystals were developed, with many belonites of a silicate, with spherulites and a tufted growth, probably of chalcedony, and with a few grains of pyroxene. The irregular crowding of the spherulites is very noteworthy, and the effect of the surfaces of the glass on the grouping of the structures produced by the alteration. A study of M. Daubrée's remarks and plates appears clearly to indicate that there is a great difference between the results of mere "heat" devitrification as described above, and those of "heat-water-pressure" devitrification.

The experimental evidence above cited indicates that considerable structural change and possibly some amount of molecular segregation involving actual change of relative position (which is certainly considerable when water is present) can take place when a solid body is rendered moderately plastic, but without fusion. This is further illustrated by such facts as the kernel-roasting of copper-

* 'Etudes Synthétiques de Géologie Expérimentale,' vol. i. pp. 159–171. Composition:—

SiO_2	68·4
Al_2O_3	4·9
CaO	12·0
MgO	·5
Na_2O	14·7
	100·5

ore. That similar processes can go on in nature is suggested by the numerous instances which we witness in studying the conversion of olivine-rock into serpentine, of pyroxene into varieties of hornblende, the formation of tourmaline in granite, and the like. I believe also that many of the oolitic grains in limestones are structurally true "spherulites" developed after the rock was more or less consolidated; and that such is the nature of the radiate balls in the magnesian limestones of Durham can hardly be doubted. Many other instances of "concretion" might readily be mentioned, notably those singular forms in the flinty slates of Eskdale; but the above may suffice. I formerly pointed out that the spherulitic structure of certain felsites in Arran could only be explained on the supposition that they had been produced by a metamorphic action due to a subsequent intrusion of an igneous rock. The structures of the devitrified glasses also show us very clearly how great an influence the slightest disturbance of equilibrium has on the initiation and direction of crystal-growth. The discontinuity, and consequent difference, due to the mere existence of a surface—what we may term the surface tension—has sufficed to originate crystallization in each one of these cases of artificial secondary devitrification.

Thus my examination of a large number of igneous rocks in the light obtained from the experimental evidence described above leads me to the following conclusions:—

(1) That spherulitic and other microlithic structures can be produced in a glassy rock during cooling.

(2) That they may sometimes originate from a nidus (as it were) of slightly different mineral composition, which thus starts crystallization.

(3) That they very often originate by the mechanical aid of some included crystal or particle.

(4) That perhaps still more often they are the result of some kind of strain analogous to that of the artificial cases described above. This might occur especially in banded rocks, as the difference in composition in the layers might cause them to contract unequally.

(5) That these microlithic structures, unless too crowded, are sharply separated from the surrounding glass.

(6) That they can also be produced by subsequent heating short of fusion, and that, except perhaps that the results are more obviously connected with local disturbance of equilibrium, there are no means of distinguishing between "dry heat" devitrification and "slow cooling" devitrification.

But the experiments of Prof. Daubrée have produced results not wholly identical with those of the dry-heat action; and to this experiment the process which has taken place in nature must have been more nearly analogous; that is to say when "devitrification," in the strict sense of the word, has been produced in a rock once glassy, the agents of change have been pressure, water, heat, the elevation of temperature being probably in most cases very moderate. How far, then, is it possible to distinguish the results of this from those of "cooling devitrification," the only other kind likely to occur, except very locally, in nature?

An examination of Prof. Daubrée's results suggests that the devitrifying action has been more universal and simultaneous throughout the mass than in the above-described cases of "dry heat" or "cooling" devitrification. It is true that the surfaces of the mass have, in this case also, produced modifications; but spherulites appear to have started almost simultaneously from many independent centres, so as to form a crowded mass, interlocking with irregular outlines, instead of a number of large spherulites, which, if they come into contact, are parted by more uniform surfaces. The formation also of innumerable microliths throughout the whole mass of the glass is not well paralleled in the instances of "dry-heat" devitrification. Now on examining cases where we may reasonably conclude that a devitrification (in the strict sense of the word) has occurred in nature, we are struck with certain structural peculiarities. We may, I think, assume that the existence of a perlitic structure in a rock is an indication that it has once been a true glass. Isolated spherulites and a well-marked banded structure are, I believe, also presumptions in favour of the same; though in the latter case portions may have assumed a crystalline condition in cooling. If, then, we examine slides of such rocks as the devitrified perlitic lavas of the Wrekin district, we observe that the secondary structure presents certain peculiarities. Not seldom it bears a definite relation to the cracks by which the perlitic mass is traversed, a thing not surprising, because these cracks, as pointed out some years since by myself, and as indicated to you during the present year from another point of view by Mr. Rutley, may have from the very first been connected with pressures or strains of some kind, and this disturbance of equilibrium could scarcely fail to tell when crystallization commenced. There are, indeed, instances to be found where the depolarization-phenomena ordinarily seen in a colloid body subject to strain seem to have been rendered permanent. The devitrification-structures in these perlitic rocks differ much from those which I have observed in any case where there was a reasonable probability of their being the result of the original cooling. It is difficult to express it in words, without entering into lengthy and minute details unfitted for the present occasion; but I may epitomize them thus:—the slide throughout exhibits a peculiar confusedly crystalline structure, the individualized minerals sometimes being of extreme minuteness. The ground-mass appears to be composed of a mixture of quartz and felspar; but it is exceedingly difficult to say which has been first to consolidate, sometimes the one, sometimes the other, appearing to have had the mastery. Now and then a felspar crystal exhibits a rectilinear boundary, but very commonly it appears to granulate into the quartz, and sometimes the felspathic mineral (I am doubtful whether it is a true felspar) resembles a kind of residuum or "sediment," left unused when the quartz grain had formed. The latter mineral frequently occurs in little groups of moderately distinct, though crowded crystals, as may be observed in some cases of chalcedonic formation in veins and cavities. Close intercrystallizations of the quartz and felspars, leading to all kinds of imperfect spherulitic, micrographic, and den-

dritic structure *, are common; and not seldom tiny spherulites occur, whether singly or in crowded groups, of that indefinite external character already mentioned. In short we have a number of structures similar, so far as I can judge, to those figured by MM. Fouqué and Lévy in their magnificent work 'Minéralogie micrographique,' plates xi., xii.(2), xiv., xv., and xvi. (1): in the last, I believe, at any rate the larger spherulites are of anterior consolidation. I have found characters more or less similar prevail in the "felstones" beneath the base of the Cambrian of North and South Wales, in the compact lavas from Charnwood, in the more compact of the Ordovician lavas from Wales, and in many other similar rocks. It is, in fact, generally found in those "felstones" which have a compact, smooth, and sometimes subconchoidal fracture, but hardly so much as a glimmering lustre.

Hence it appears to me that the petrosiliceous structure of the above-described character is probably always the result of secondary devitrification, in which pressure and water (acting for a long time) have been more important than heat. It has nearer relations to the microgranulitic structures found in certain vein-granites and intrusive felstones than to the trachytoidal structure of lava-flows; which is not surprising, seeing that the former structures have probably been set up under considerable pressure and in the presence of water. Thus we appear to have two groups of structure: one, the trachytoidal and ophitic, which are more generally the results of drier and less constrained cooling; the other, the petrosiliceous, microgranulitic, and granitoidal, indicative of the presence of some water and the existence of much constraint, the first of these three being probably almost entirely a structure of secondary origin; for I expect that we shall find on further study that we shall be able to distinguish even the more minutely microgranulitic rocks from the truly petrosiliceous; but on this point I will not venture to speak at all positively, as I have not been able to study so many specimens of these vein-granites as I should wish to have done. Still I think we may safely affirm that the majority of the petrosiliceous rocks owe their structure to a peculiar form of subsequent devitrification, and so, as *altered* rhyolites, obsidians, and pitchstones, belong more properly to the metamorphic rocks (of igneous origin).

I have throughout spoken, as I stated I should do, with little reference to the work of others, because I thought that there might be a certain interest and advantage in presenting what I had to say from a personal point of view, since on nearly every point I have striven to form an independent conclusion, and often the result of many hours' work has been condensed into a few words. It has been work, I fear you will say, leading to little result; but perhaps its very incompleteness may suggest lines of research to other workers. Another reason why I have referred little to the investigations of others is, that in each case one ought in justice to be sure of naming the original observer. Now to do this would have involved much

* I use the last term for want of a better name to express cases where the minerals resemble crowded branches or rootlets.

additional labour, of a kind unprofitable to one's self. The great demands made upon my time for the last four years by duties only indirectly connected with science have compelled me to be a little selfish, and have precluded me from the careful study of a good deal of contemporary literature, now becoming fearfully voluminous. But I cannot conclude without stating how much I owe to many fellow-workers—to Daubrée, Fouqué and Lévy, in France, to Renard in Belgium, to Vogelsang, Rosenbusch, and Zirkel, in Germany, to many Americans, above all Wadsworth and Dutton, and, in our own country, to Sorby, Phillips, Teall, Judd, and Allport; all of these last named have aided me in every possible way, freely furnishing me with specimens and frankly imparting to me their own ideas. To the last, Mr. S. Allport, I feel myself under a special obligation. Fourteen years ago, when I began to study the microscopic structure of rocks, there were few books and, in England, very few petrologists. Mr. Allport had already more than mastered the preliminary difficulties, and had got together a fine collection of rock-slides, his own handiwork. This collection and all that he knew were at my service whenever I could visit Birmingham. To him I used to carry my perplexities, and from him I got that help which, in my new stage of work, was invaluable. I can say with truth that had it not been for his assistance, as well as your indulgence, I might never have attained to the honour of addressing you from this chair.

February 25, 1885.

Prof. T. G. Bonney, D.Sc., LL.D., F.R.S., President, in the Chair.

Bennett Hooper Brough, Esq., Assoc. R.S.M., 5 Robert Street, Adelphi, W.C.; Parvati Nath Datta, Esq., 10 Blackwood Crescent, Edinburgh; Robert Stansfield Herries, Esq., B.A. Cambr., 53 Warwick Square, London, S.W.; William Herbert Herries, Esq., B.A. Cambr., Shaftesbury, Te Aroka, Auckland, New Zealand; Rev. Edward Jordon, Ravenscroft Park, High Barnet, N.; Lees Knowles, Esq., M.A., LL.M., Westwood, Pendlebury, near Manchester; and William Hobbs Shrubsole, Esq., Sheerness, were elected Fellows of the Society.

The List of Donations to the Library was read.

The following communications were read:—

1. "On a Dredged Skull of *Ovibos moschatus*." By Prof. W. Boyd Dawkins, M.A., F.R.S., F.G.S.

2. "On Fulgurite from Mont Blanc." By Frank Rutley, Esq., F.G.S.

3. "On Brecciated Porfido-rosso-antico." By Frank Rutley, Esq., F.G.S.

4. "Fossil Cyclostomatous Bryozoa from Aldinga and the River-Murray Cliffs, South Australia." By Arthur Wm. Waters, Esq., F.G.S.

The following objects were exhibited:—

Specimens, exhibited by Frank Rutley, Esq., F.G.S., in illustration of his papers.

A collection of stone implements and two cut bones from the neighbourhood of Reading, Berks, exhibited by O. A. Shrubsole, Esq., F.G.S.

Two old oil-paintings of Vesuvius in eruption, exhibited by George Ellis, Esq.

March 11, 1885.

Prof. T. G. Bonney, D.Sc., LL.D., F.R.S., President, in the Chair.

William Lester, Esq., J.P., Bron Offa, near Wrexham, and

Thomas Stewart, Esq., Assoc. M. Inst. C.E., Cape Town, were elected Fellows of the Society.

The List of Donations to the Library was read.

The following communications were read:—

1. "The Granitic and Schistose Rocks of Northern Donegal." By C. Callaway, D.Sc., F.G.S.

2. "On Hollow Spherulites and their occurrence in ancient British Lavas." By Grenville A. J. Cole, Esq., F.G.S.

Rock specimens and microscopic sections were exhibited by Dr. Callaway and Mr. Grenville Cole in illustration of their papers.

March 25, 1885.

Prof. T. G. Bonney, D.Sc., LL.D., F.R.S., President, in the Chair.

Charles De Laune Faunce de Laune, Esq., F.L.S., Sharsted Court, Sittingbourne, Kent; and William Hill, Esq., Jun., The Maples, Hitchin, Herts, were elected Fellows of the Society.

The List of Donations to the Library was read.

The following communications were read:—

1. "On the Relationship of *Ulodendron*, Lindley and Hutton, to *Lepidodendron*, Sternberg, *Bothrodendron*, Lindley and Hutton, *Sigillaria*, Brongniart, and *Rhytidodendron*, Boulay." By Robert Kidston, Esq., F.G.S.

[Abstract *.]

The Author commenced by expressing an opinion that the so-called genus *Ulodendron* of Lindley and Hutton comprised specimens belonging to several species which were referred to different genera. Unless the outer surface of the bark is well preserved, stems of Clathrarian *Sigillariæ* and *Lepidodendra* are undistinguishable; but species of *Ulodendron* have been in several cases founded on decorticated examples, and distinguished by such characters as the size of the Ulodendroid scar. The three species which have furnished most of the specimens described as *Ulodendron*, and to the description of which the present paper was chiefly devoted, are *Lepidodendron Veltheimianum*, Sternb., *Sigillaria discophora*, König, sp. (= *U. majus* and *U. minus*, Lindl. & Hutt.), and *S. Taylori*, Carruthers, sp.

* This paper has been withdrawn by permission of the Council.

The subject of the paper was divided into four heads. In the first an epitome of the views of previous writers on *Ulodendron* was given. The writers noticed were Steinhauer, Rhode, Allan, König, Sternberg, Brongniart, Lindley and Hutton, Buckland, Hooker, Sauveur, Unger, Göppert, Tate, Geinitz, Goldenberg, Miller, Eichwald, Macalister, Dawson, Carruthers, Röhl, Schimper, Weiss, Williamson, Feistmantel, Stur, Thomson, Zeiller, Lesquereux, and Renault. In the second part the Author described the specimens belonging to the species named that he had been able to examine.

The third part contained the general conclusions as to the nature of *Ulodendron* at which he had arrived. He commenced by defining the four genera *Lepidodendron*, *Lepidophloios*, *Sigillaria*, and *Rhytidodendron*, as distinguished by the characters of their leaf-scars, and showed that *Lepidodendron*, *Sigillaria*, and *Rhytidodendron* occasionally exhibit large scars, arranged in two opposite vertical rows. These are the Ulodendroid scars. They marked, in the Author's opinion, the point of attachment of a caducous appendicular organ, which had in a very few cases been found in position. These appendicular organs were probably sessile cones. Details were given, showing the progressive development of the scars, the obliteration of the normal leaf-scars by the appendicular organs, and the branching of Ulodendroid stems.

The concluding portion of the paper contained the synonymy at length and full descriptions of the three fossil plants, *Lepidodendron Veltheimianum*, *Sigillaria discophora*, and *S. Taylori*, together with the horizons and localities in which they have been found in Britain. *Bothrodendron* was shown to be a decorticated form of Ulodendroid stem, and *Knorria* a cast of the core of *Lepidodendron*.

Discussion.

Mr. Carruthers, after expressing his sense of the value of the paper, remarked upon the difficulty of finding characters of real importance for grouping fossil plants; hence fossil species and genera are based on very different data from those of recent plants. All the essential characters of the Carboniferous Lycopodiaceæ, for example, may be found in the recent genus *Selaginella*. When he himself wrote on the subject he merely accepted the characters of *Ulodendron*, and his only important difference from the Author was as to the organs borne by the Ulodendroid scars. There was a difficulty in the way of accepting them as cones in the fact that the scar is surrounded by a ring or distinct cicatrix where there was a connexion of tissue; if so, impressions of leaves within the scar could not be left. All the markings on the lower portion of the scar are circular, indicating the places where vascular bundles passed through. In the upper part they are drawn out. Hence he had considered the organs borne by these scars as aerial roots, such as occur in the *Selaginellæ* of the present day, allied to the Lycopods of the Coal-measures. The important point is, whether the

marks on the scar are marks of leaves or marks of bundles. Probably these scars are found in different genera, but the scars may be of as great importance as the leaf-scars themselves for grouping the plants in genera. He thought the cushions and permanent leaf-bases, as in some living Cycads and Lycopods, were parts of the leaf, not parts of the stem.

Prof. Boyd Dawkins said that he had a large collection of Coal-plants under his charge in the Manchester Museum, including forms similar to those exhibited by the Author. This collection throws much light upon Lepidodendroid plants, and he agreed with the Author as to the propriety of classing together the various forms of *Lepidodendra* and *Sigillariæ*. Prof. Williamson regarded all the species named as merely forms of Lepidodendroid plants. He was inclined to regard the Ulodendroid scars as impressions of seed-cones, and not of aerial roots, because on the best specimens of these scars there are impressions of whorls of leaves or modified leaves. In these plants the bark consists of several layers; hence arise the various patterns exhibited, which have led to the establishment of different genera.

Prof. Seeley said that in former years he had worked through some collections of Coal-plants. If *Ulodendron* were a good genus, then the internal difference of structure between *Sigillaria* and *Lepidodendron* could not be general. The character of *Ulodendron* is apparently of not less value morphologically than the form of the leaf-scar. And, whatever the *Ulodendron* structure implied, Ulodendroid scars had been described by M'Coy in a slightly modified Sigillarian trunk, running round the stem instead of vertically. M'Coy thought that they were the places of attachment of rootlets. The phenomena seemed to be in favour of the development of fruit-organs, and not of roots from the Ulodendroid scars.

The Author, in reply, remarked on the generic distinctions between the leaf-scars of *Lepidodendron* and *Sigillaria*. The constancy of leaf-scars throughout the plants shows that there are real generic distinctions between them. Some of the specimens exhibited showed the mode of attachment of the appendicular organ, and these could not be scars of appendicular roots, because they contain markings due apparently to leaves. The particular specimen on which Mr. Carruthers mainly founded his notion of aerial roots was not, in the Author's opinion, Ulodendroid at all. The genus *Arthropilus*?, described by M'Coy, was founded on a badly preserved compressed stem.

2. "On an almost perfect Skeleton of *Rhytina gigas* = *Rhytina Stelleri* ('Steller's Sea-cow') obtained by Mr. Robert Damon, F.G.S., from the Pleistocene Peat-deposits on Behring's Island." By Henry Woodward, LL.D., F.R.S., F.G.S.

The following specimens were exhibited:—

Recent skulls of male and female Dugong (*Halicore australis*) and

skull of *Manatus senegalensis*, also casts of bones of the extinct *Rhytina* from Behring's Island, exhibited by Dr. Henry Woodward, F.R.S., F.G.S., in illustration of his paper.

A collection of plant-remains, exhibited by R. Kidston, Esq., F.G.S., in illustration of his paper.

Photographs of *Elasmotherium* from Post-Tertiary deposits at Novousenk, Gov. Samara, Russia, exhibited by Dr. Henry Woodward, F.R.S., F.G.S.

April 15, 1885.

Prof. T. G. Bonney, D.Sc., LL.D., F.R.S., President, in the Chair.

John Rudd Leeson, M.D., C.M. (Edin.), M.R.C.S. Eng., 6 Copthall, Twickenham, Middlesex, was elected a Fellow of the Society.

The List of Donations to the Library was read.

The Secretary announced that a Kit-cat portrait of the late Sir Henry De la Beche, painted in oil-colours by H. W. Pickersgill, R.A., had been presented to the Society by the President; and that Messrs. Maull and Fox had presented 146 copies of photographs of Fellows of the Society.

The following communications were read:—

1. "A General Section of the Bagshot Strata from Aldershot to Wokingham." By the Rev. A. Irving, B.Sc., B.A., F.G.S.

2. "Notes on the Polyzoa and Foraminifera of the Cambridge Greensand." By G. R. Vine, Esq. (Communicated by Thomas Jesson, Esq., F.G.S.)

[Abstract.]

After commenting on the want of published information concerning the Polyzoa of the Cambridge Greensand, as shown by the fact that none are mentioned in Mr. Jukes-Browne's list of the fossils (Quart. Journ. Geol. Soc. xxxi. p. 305), the author proceeded to explain the circumstances under which he had been entrusted with the whole of Mr. T. Jesson's collection from the coprolite-bed for description. The collection is large and important, and the Polyzoa contained in it exhibit a facies distinct from that of the Jurassic beds on the one hand and of the Upper Chalk on the other. There is but little similarity between the collection now described and the forms known from Warminster and Farringdon. The majority of the Cambridge-Greensand Polyzoa occurred unattached to any matrix;

but several examples of attachment have been observed, chiefly to *Ostrea*, *Radiolites*, and species of *Cidaris*.

A list showing the range of the species described preceded the actual descriptions of the following kinds of Polyzoa and Foraminifera, with notes on their relations &c. It included:—

POLYZOA.

Stomatopora gracilis, *Milne-Edw.*
Idmonea dorsata, *Hagenow.*
Entalophora raripora, *D'Orb.*
—— Jessonii, sp. nov.
—— striatopora, sp. nov.
—— gigantopora, sp. nov.
Diastopora cretacea, *Vine.*
—— ——, var. lineata, var. nov.
—— fecunda, sp. nov.
—— megalopora, sp. nov.
Lichenopora, sp.
—— ? paucipora, *Vine.*
Dromopora stellata, *Goldfuss.*
—— polytaxis, *Hagenow.*
Osculipora plebeia, *Novall.*
Truncatula, sp.
Membranipora cantabrigiensis, sp. nov.
Microporella, sp. (? antiquata).
Lunularia cretacea, *Defr. & D'Orb.*

FORAMINIFERA.

Webbina lævis, *Sollas.*
—— tuberculata, *Sollas.*
Trochammina irregularis ?, *D'Orb.*
Textularia, sp.

The following specimens were exhibited:—

Specimens exhibited by the Rev. A. Irving, F.G.S., and G. R. Vine, Esq., in illustration of their papers.

Sand-worn stones from Hokitika, New Zealand, exhibited by W. D. Campbell, Esq., F.G.S.

Specimens illustrating the paper lately read by J. H. Collins, Esq., F.G.S., on the Rio Tinto district.

April 29, 1885.

Prof. T. G. BONNEY, D.Sc., LL.D., F.R.S., President, in the Chair.

James Backhouse, Esq., West Bank, York; Percy Bosworth Smith, Esq., Assoc. R.S.M., Government Mineralogist to the Madras Presidency, Madras; and James Shipman, Esq., 8 Manning Grove, The Chase, Nottingham, were elected Fellows of the Society.

The List of Donations to the Library was read.

The following communications were read:—

1. "On the Structure of the Ambulacra of some Fossil Genera and Species of Regular Echinoidea." By Prof. P. Martin Duncan, M.B. (Lond.), F.R.S., V.P. Linn. Soc., F.G.S.

2. "The Glacial Period in Australia." By R. von Lendenfeld, Ph.D. (Communicated by W. T. Blanford, LL.D., F.R.S., Sec. G.S.)

[Abstract.]

Although several previous writers have suggested that boulders and gravels found in different parts of Australia are of glacial origin, the evidence is vague, and no clear proof of glaciation has been brought forward. During a recent ascent of the highest ranges in Australia, parts of the Australian Alps, the author succeeded in discovering a peak which he named Mount Clarke, 7256 feet high, and in finding traces of glaciation in the form of *roches moutonnées* throughout an area of about 100 square miles. The best-preserved of the ice-worn surfaces were found in a valley named by the author the Wilkinson Valley, running from N.E. to S.W., immediately south of Müller's Peak and the Abbot Range. No traces of ice-action were found at less than 5800 feet above the sea.

The rocks showing ice-action are all granitic, and the fact that the surfaces have been polished by glaciers is said to be proved by the great size of such surfaces, by their occurrence on spurs and projecting points, by many of them being worn down to the same general level, and by their not coinciding in direction with the joints that traverse the rock.

In conclusion the author briefly compared the evidence of glacial action in Australia with that in New Zealand.

Discussion.

The President said that he considered that more evidence was necessary in order to establish the point contended for by the author. All his proofs were founded on granite, which had a constant tendency to form rounded bosses. The fact that the supposed *roches moutonnées* occurred on spurs rendered the matter still more doubtful, seeing that in small glaciated tracts such surfaces were chiefly found in valleys. It was a remarkable and, to him, a very suspicious fact that no moraines or perched blocks were noticed. In fact the only point of importance adduced in favour of the author's view seemed to be the difference in the direction of the joint-planes and of the rounded surfaces, and this he thought insufficient.

Mr. Blanford agreed with the President, and mentioned examples of the occurrence, in the plains of India, where glaciation was out of the question, of granite surfaces simulating *roches moutonnées,* and of larger dimensions than those cited by the author. It seemed to him not impossible that Dr. von Lendenfeld was right; but the evidence brought forward was certainly not sufficient. The circumstance most in favour of a glacial origin for the supposed *roches moutonnées* was their restriction to a particular elevation.

3. "The Physical Conditions involved in the Injection, Extrusion, and Cooling of Igneous Matter." By H. J. Johnston-Lavis, M.D., F.G.S., &c.

[Abstract *.]

The great disproportion between the displays of volcanic activity

* This paper has been withdrawn by permission of the Council.

in the same volcano at different times, and between the eruptions of different volcanoes, is a subject deserving the most attentive consideration. The violence of a volcanic outburst does not bear any relation to the quantity of material ejected. The union of water with lavas may be compared with the solution of a gas in water; but there is reason to believe that in their deep-seated sources lavas contain little or no water. If igneous matter be extruded through dry strata, the eruption might take place without explosive manifestations. But if igneous matter be extruded through water-bearing beds, a kind of dialysis would take place between the igneous and aqueous masses. The amount of water dissolved in the magma will be proportienal to the length of time it is in contact with the aquiferous strata, the pressure, and the temperature of the fluid rock; the violence of the eruption will depend upon the amount of igneous matter, the quantity of water dissolved in it, and its temperature when it reaches the surface.

The intrusion of igneous matter into dry or nearly dry strata, the temperature and bulk of the magma will determine whether a sahlband is formed, or formed and re-fused, whether the rock cools quickly, forming a fine-grained structure, or very slowly, in which the result would be a coarse granite or syenite, according to the composition of the magma.

The author showed how the cleavage- and stratification-planes of rocks are suitable to the retention of subterranean heat. Intrusion of igneous matter into water-bearing strata was then studied, and it was shown that a process of dialysis goes on between the colloidal magma and the water in the porous strata, resulting in many interesting phenomena. The loss of heat in the magma from the absorption of water will be little, and only that necessary to raise the water to its own temperature. It was shown how this absorption of water will result in the rupturing of the fissure towards the surface; and the mechanism of a certain group of earthquakes was investigated. The occurrence of vesicular structure in dykes was discussed; the mode of formation and probable process of re-obliteration is dependent upon the variation in pressure, temperature, &c. resulting from the enlargement of the fissure. It was then shown that the cooling of a dyke-mass will depend on the following conditions:—

(*a*) Loss of heat from conduction away by the surrounding rocks.

(*b*) Raising the acquired water to the mean temperature of the fluid of the fused silicates in which it is dissolved.

(*c*) Heat-loss in consequence of expansion during extension of fissure.

(*d*) Gradual escape of water in the form of steam or vapour through fissures, so supplying fumaroles.

(*e*) Convection-currents of water forming geysers or thermo-mineral springs.

The author combatted the theory that the simple contact of the molten rock with water-bearing strata is the cause of an eruption.

The extrusion or eruption of igneous matter into the atmosphere was then studied, and it was shown that one of the irregularities in eruptive activity is due to the varying conditions which different parts of the magma have undergone before reaching the surface. The main varieties of volcanic outbursts were discussed: the violence is dependent upon the amount of magma and its contained water, which on relief of pressure expands with enormous rapidity, tending to reduce the whole mass to 100°. This process in explosive eruptions accounts for the pumice and the vitreous structure of this type of eruption. The remarkable fact that the pumice-beds resulting from any basic explosive eruption are vitreous towards the bottom and become more crystalline as we approach the surface, was shown to be due to the slower cooling in consequence of less absorption of heat in converting water into steam as the eruption progresses.

The various conditions which bring about the extinction of a volcano were then pointed out. The higher the volcano the more violent will be its eruptions; but the intervals will be greater. The mechanism of a lateral outburst was then demonstrated. The amount of lava escaping from a given point laterally is far more than that contained in the chimney above, which is due to the welling-up of the portion below when relieved from the pressure of the column that occupied the upper part of the chimney.

The discussion of the effect of the presence of volatile matter in modifying the composition and structure of igneous rocks is so long and intricate that it is impossible to render it in abstract; the eruptive phases of Monte Somma, Roccamonfina, Monte Vulture, Ventotene, and Monte Nuovo are given as examples. The difference of the rocks produced will depend on—

(*a*) Composition of the original magma.
(*b*) Pre-eruptive temperature of the same.
(*c*) Amount of enclosed volatile matter.
(*d*) Amount of pre-eruptive crystallization.
(*e*) Rapidity of ejection.
(*f*) Height of projection.
(*g*) Temperature of the atmosphere.

In the first appearance of a volcano, or the reawakening of one, vitreous pumiceous fragmentary products first appear, and pass by way of more microcrystalline pumice, pumiceous scoria, to actual lava outflows. Scoria differs from pumice in that the vesicular structure is derived from other portions of the magma, whereas in pumice it is formed, where found, by the intermolecular expansion and union of the resulting steam into bubbles. Vesicularity of lavas depends upon the amount of dissolved water and the viscosity of the mass.

Volcanic ashes are the result either of the complete reduction of the magma to a powder by the enormous and rapid expansion of the magma in explosive eruptions, or of the grinding-up of the *accessory* ejectamenta derived from the crater-sides or from *accidental* ejectamenta that may lie beneath the volcano, and into which the apex

of the crater may reach. In no case can an analysis of ash give an accurate idea of the composition of the magma.

The structure and composition of igneous rocks were next discussed. It was shown that such minerals as amphibole, orthoclase, and some micas are pre-eruptive as to crystallization, whereas leucite and its allies, with pyroxene, are either formed in dykes under low pressure or by prolonged *recuit* in the volcanic chimney, or after expulsion. The order of formation of these minerals is quite different from their fusibilities, because they may be regarded as dissolved in the magma, and separate according to their degree of solubility in the glassy magma and according to the different elements, their proportions, and their affinities. The part played by the chlorides and sulphates as solvents of silicates was discussed, and it was shown how by their decomposition the hydrochloric and sulphuric acids escape in the volcanic vapour, and how the bases may aid in rendering the magma more basic. These facts are borne out in the artificial production of rocks and minerals.

The author maintained that throughout the whole paper his arguments were based on known facts and physical laws.

Discussion.

Prof. Prestwich was inclined to agree with the author in his view that the contact of heated lava with water-bearing strata was an efficient cause of volcanic activity, but on some other points he could not agree with him.

The following specimens were exhibited:—

Specimens of Echinoderms showing the structure of the ambulacra, exhibited by Prof. P. Martin Duncan in illustration of his paper.

May 13, 1885.

Prof. T. G. Bonney, D.Sc., LL.D., F.R.S., President, in the Chair.

William Horton Ellis, Esq., J.P., Hartwell House, Pennsylvania, Exeter, and Prof. J. Hoyes Panton, M.A., Agricultural College, Guelph, Ontario, were elected Fellows; and Prof. J. Gosselet, of Lille, a Foreign Member of the Society.

The List of Donations to the Library was read.

The Secretary announced that Dr. John Evans, F.R.S., F.G.S., had presented a copy of his photographic portrait.

The following communications were read:—

1. "On the Ostracoda of the Purbeck Formation; with Notes on the Wealden Species." By Prof. T. Rupert Jones, F.R.S., F.G.S.

2. "Evidence of the Action of Land-ice at Great Crosby, Lancashire." By T. Mellard Reade, Esq., F.R.S.

3. "The North-Wales and Shrewsbury Coal-fields." By D. C. Davies, Esq., F.G.S.

[Abstract *.]

After discussing the origin of Coal-beds, and the causes of their variation in structure and quality, the author proceeded to describe the North Wales and Shrewsbury Coal-field, which consists of three parts:—(1) The Shrewsbury field south of the Severn, exclusively composed of Upper Coal-measures; (2) the tracts north of the Severn, extending from near Oswestry to north of Wrexham; and (3) the Flintshire Coal-field. The first and second are separated from each other by the alluvial plain of the Severn and Vyrnwy, and the second and third by the Great Bala and Yule faults.

Some remarks on the scenery of the Welsh border-land followed, and then a general section of the Carboniferous system, as developed in the country described, was given, the Permian beds being included, as the Author considered them the upper portion of one great division of Palæozoic time. The section was as follows, with the maximum thickness of each subdivision:—

	Thickness in yards.	
1. Dark red Sandstone	210	Permian, 590 yards.
2. Ifton or St. Martin's Coal-measures	75	
3. Red marls with calcareous matter	180	
4. Green rocks and Conglomerates	125	
5. Upper Coal-measures	80	Coal-measures, 665 yards.
6. Cefn rock to Cefn coal	100	
7. Cefn coal to Lower yard-coal	270	
8. Lower yard-coal to Chwarcle coal	80	
9. Chwarcle coal to Millstone Grit	135	
	1255 yards.	

A detailed description of the strata was next given, beginning with the lowest, together with details of each coal-seam as worked in various parts of the field. After describing the beds from the Millstone Grit to the Cefn rock in the North-Wales coal-field, the Author proceeded to notice the Upper Coal-measures and Permian strata in the Shrewsbury area, and showed that no break exists between the two, the former passing gradually into the latter. He then discussed the probability of Lower Coal-measures existing beneath the upper beds near Shrewsbury, and showed from sections that the existence of the lower measures might be anticipated. A similar inquiry as to the presence of the Coal-measures beneath the New Red Sandstone of the Vale of Clwyd should also, in the Author's opinion, be answered in the affirmative.

The organic remains found in the different beds were briefly noticed, and then the faults of the district were discussed at some

* This paper has been withdrawn by permission of the Council.

length. The principal faults run north and south, with an upthrow to the east, but are crossed by lines of fracture running east and west.

In conclusion, the correlation of the strata in the North Wales and Shrewsbury coal-fields, and especially of the coal-seams, with the beds found in other parts of Great Britain, was discussed, and a section was given to show the representation of the different measures in various coal-basins. The Author was disposed to adopt four subdivisions rather than three only, as usually accepted, and pointed out some of the characteristics of each subdivision.

Discussion.

Mr. Bauerman remarked that but little attention had hitherto been paid to the interesting Coal-fields described by the Author, to whom thanks were due for the careful sections which he had made of them. Although the yield of these basins was not large when compared with those of the north of England and South Wales, they formed part of one of the largest deep-lying Carboniferous areas in the country, being the western limit of the great basin underlying the plain of Cheshire. He thought, however, that the Author's correlation of the seams throughout the whole of the English Coal-field (apart from that of Northumberland and Durham) was somewhat fanciful. That particular seams, say in the Wigan district, could be proved to be the exact equivalents of others in South Wales, and that both were exactly represented in intermediate basins, such as the Forest of Wyre, appeared to be exceedingly improbable.

The following specimens were exhibited:—

Specimens of Purbeck Ostracoda, exhibited by Prof. T. Rupert Jones, F.R.S., F.G.S., in illustration of his paper.

Zinc-spinel and willemite, formed in a zinc-retort, exhibited by H. Bauerman, Esq., F.G.S.

May 27, 1885.

Prof. T. G. Bonney, D.Sc., LL.D, F.R.S., President, in the Chair.

George Ormond Kekewich, Esq., 62 Lansdowne Road, Notting Hill, W., was elected a Fellow of the Society.

The List of Donations to the Library was read.

The Secretary announced that six slides of Fossil Cyclostomatous Bryozoa from Muddy Creek, South Australia, illustrating the paper in Q. J. G. S. vol. xl. p. 674, by A. W. Waters, Esq., F.G.S., had been presented to the Museum by J. Bracebridge Wilson, Esq., of Geelong, South Australia.

The following communications were read:—

1. "On the so-called Diorite of Little Knott (Cumberland), with further Remarks on the Occurrence of Picrites in Wales." By Prof. T. G. Bonney, D.Sc., LL.D. F.R.S., Pres.G.S.

2. "Sketches of South-African Geology.—No. 2. A Sketch of the Gold-Fields of the Transvaal, South Africa." By W. H. Penning, Esq., F.G.S.

3. "On some Erratics in the Boulder-clay of Cheshire &c., and the Conditions of Climate they denote." By Charles Ricketts, M.D., F.G.S.

The following specimens were exhibited:—

Microscopic rock-sections and rock specimens, exhibited by the President, in illustration of his paper.

Boulders, &c., exhibited by Dr. Ricketts, in illustration of his paper.

June 10, 1885.

Prof. T. G. Bonney, D.Sc., LL.D., F.R.S., President, in the Chair.

The List of Donations to the Library was read.

The following names of Fellows of the Society were read out for the first time, in conformity with the Bye-laws Sec. vi. B. Art. 6, in consequence of the non-payment of the arrears of their contributions:—G. Bock, Esq., Rev. S. Gasking, and W. Low, Esq.

The following communications were read:—

1. "Note on the Sternal Apparatus in *Iguanodon*." By J. W. Hulke, Esq., F.R.S., V.P.G.S.

2. "The Lower Palæozoic Rocks of the Neighbourhood of Haverfordwest." By J. E. Marr, Esq., M.A., F.G.S., and T. Roberts, Esq., B.A., F.G.S.

3. "On certain Fossiliferous Nodules and Fragments of Hæmatite (sometimes Magnetite) from the (so-called) Permian Breccias of Leicestershire and South Derbyshire." By W. S. Gresley, Esq., F.G.S.

[Abstract.]

In this paper the author described certain pebbles of hæmatite and magnetite which occur in the so-called Permian breccias on

the western margin of the Ashby-de-la-Zouch Coalfield. These pebbles, which are collected for sale and used as "burnishers" (for which their extreme hardness qualifies them) vary from a diameter of $\frac{1}{10}$ inch to the size of a man's fist. They present many varieties of form, usually rounded and often very smooth, angular, and subangular; a few contain cavites, which are often lined with fibrous botryoidal ore, or contain a group of crystals of calcite, or a kernel of soft pea-ore; have sometimes an agate-like, and rarely a columnar structure, and occasionally exhibit well-marked magnetic polarity, others being simply magnetic. Sometimes they show dimpling, also grooving and striation resembling those produced by ice-action, whilst at other times they seem to have been crushed and recemented; many of these markings are doubtless due to oscillatory movement of the rocks *en masse*. Many of these pebbles contain fossils of various kinds, chiefly plant- and insect-remains, but with a few of Annelids, Mollusca, and Fish (?). All the fossils are of Carboniferous age (Coal-measures, for the most part). Amongst the associated rock-fragments in the breccias many bits exhibiting cone-in-cone structure occur, composed chiefly of a close-grained quartzose material; and a specimen showing the cones whose axes lie in radiating lines (the cones facing upwards, downwards, and sideways or fan-shaped) has been noticed for the first time.

From the consideration of all the facts detailed in the paper, the Author concluded that the nodules were originally composed of clay-ironstone, and that they were derived from the Coal-measures, whilst other fragments were possibly of older date. He considered that the pseudomorphic action by which they have acquired their present composition must have taken place *in situ* since their inclusion in the breccia.

Discussion.

The President believed, from a study of the specimens in the Jermyn-Street Museum, that there was no evidence of the action of ice in the Permian breccias to which allusion had been made by the Author, but that the striation of the fragments, like the dimpling and crushing in the pebbles of more than one conglomerate, were due to movements of the rocks.

Prof. Hughes regretted the absence of specimens. He could not understand the identity in mineralogical character of the pebbles with fossils, and of those with cone-in-cone structure.

The following specimens were exhibited:—

A specimen showing the clavicles and inter-clavicle of *Iguanodon*, *in situ*, exhibited by J. W. Hulke, Esq., F.R.S., V.P.G.S., in illustration of his paper.

Palæozoic fossils, exhibited by J. E. Marr, Esq., F.G.S., and T. Roberts, Esq., F.G.S., in illustration of their paper.

June 24, 1885.

Prof. T. G. Bonney, D.Sc., LL.D., F.R.S., President, in the Chair.

John Macdonald Cameron, Esq., 36 Weltje Road, Hammersmith, W.; Matthew Heckels, Esq., Walker-on-Tyne, near Newcastle-on-Tyne; and Robert H. Williams, Esq., Assoc. M. Inst. C.E., Cuddra, near St. Austell, Cornwall, were elected Fellows of the Society.

The List of Donations to the Library was read.

The following names of Fellows of the Society were read out for the second time, in conformity with the Byelaws, Sec. vi. B. Art. 6, in consequence of the non-payment of the arrears of their contributions:—C. Bock, Esq., Rev. S. Gasking, and W. Low, Esq.

The following communications were read:—

1. "Supplementary Notes on the Deep Boring at Richmond, Surrey." By Prof. John W. Judd, F.R.S., Sec. G.S., and Collett Homersham, Esq., F.G.S.

2. "On the Igneous and Associated Rocks of the Breidden Hills in East Montgomeryshire and West Shropshire." By W. W. Watts, Esq., F.G.S.

3. "Note on the Zoological Position of the genus *Microchœrus*, Wood, and its apparent Identity with *Hyopsodus*, Leidy." By R. Lydekker, Esq., B.A., F.G.S.

4. "Observations on some imperfectly known Madreporaria from the Cretaceous Formation of England." By R. F. Tomes, Esq., F.G.S.

[Abstract.]

This communication contained notes on several species of Cretaceous corals. The author considered that *Smilotrochus insignis* of Duncan must be referred to the genus *Ceratotrochus*; that *S. granulatus*, Duncan, was founded on immature specimens of *Trochocyathus Wiltshirei*, Duncan; that *Micrabacia Fittoni*, Duncan, is a variety of *Cyclocyathus Fittoni*; that the genus *Podoseris*, Duncan, and probably *Syzygophyllum*, Reuss, are the same as *Rhizangia*, M.-Edw. and Haime, and consequently *P. mamilliformis*, Duncan, and *P. elongata*, Duncan, are species of *Rhizangia*. He further stated that *Turbinoseris*, Duncan, is identical with *Leptophyllia*, Reuss, and as the specific name *de Fromenteli* is preoccupied in the latter genus, he proposed to substitute the name *Leptophyllia anglica*, Tomes, for *Turbinoseris de Fromenteli*, Duncan. A new species, probably of *Smilotrochus*, from the Gault of Folkestone, and a new *Isastræa* from Atherfield were described, and notes added on the occurrence in British localities of *Barysmilia tuberosa*, Reuss, *B. Cordieri*, M.-Edw.

and Haime, *Pleurosmilia neocomiensis*, E. de From., of a small form of *Astrocœnia*, and of *Isastræa Reussiana*, M.-Edw. and Haime (= *Ulophyllia crispa*, Reuss). The occurrence of *Beaumontia Egertoni*, derived from the Carboniferous Limestone, in the Upper Greensand of Cambridge, was also recorded.

Discussion.

Dr. Duncan said that the specimens called *Ceratotrochus* by Mr. Tomes were not before the Society, and that with one or two exceptions the other forms remarked upon were represented by very indifferent specimens. The so-called *Rhizangia* had no stoloniferous part and had synapticulæ, therefore it did not belong to the genus, but to that to which he (Dr. Duncan) had assigned the Hunstanton coral in the Palæontographical Society's Memoir. He was satisfied that the types of *Smilotrochus* he had examined, and which were well drawn by De Wilde, had no columellæ. He objected to the use of the term "imperfectly known" in the title of the paper, as it reflected even upon the work of Mr. Tomes. He would have preferred M. Cotteau's term "little known."

5. "Correlations of the Curiosity-Shop Beds, Canterbury, New Zealand." By Capt. F. W. Hutton, F.G.S.

6. "On the Fossil Flora of Sagor in Carniola." By Constantin Baron von Ettingshausen, F.C.G.S.

The following specimens were exhibited:—

Specimens, exhibited by Prof. J. W. Judd and C. Homersham, Esq., in illustration of their paper.

Rock specimens and fossils, exhibited by W. W. Watts, Esq., in illustration of his paper.

Specimens of Labyrinthodont fossils belonging to *Mastodonsaurus* and a form allied to *Capitosaurus*, from Central India, and of *Hyperodapedon*, from India and Warwickshire, exhibited by R. Lydekker, Esq.

Specimens from the well-borings at Chatham Dockyard, Crossness, and Harwich, exhibited by the Director-General of the Geological Survey.

A series of fossiliferous nodules and fragments of hæmatite from the Permian breccias of Leicestershire and South Derbyshire, exhibited by W. S. Gresley, Esq., in illustration of his paper, read on the 10th inst.

Cretaceous Corals, exhibited by R. F. Tomes, Esq., in illustration of his paper.

ADDITIONS

TO THE

LIBRARY AND MUSEUM OF THE GEOLOGICAL SOCIETY.

Session 1884–85.

I. ADDITIONS TO THE LIBRARY.

1. Periodicals and Publications of Learned Societies.

Presented by the respective Societies and Editors, if not otherwise stated.

Academy. Nos. 634–660. 1884.

——. Nos. 661–685. 1885.

Analyst. Vol. ix. Nos. 100–105. 1884.

——. Vol. x. Nos. 106–111. 1885.

Annals and Magazine of Natural History. Ser. 5. Vol. xiv. Nos. 79–84. 1884. *Purchased.*

H. J. Carter. On the *Spongia coriacea* of Montagu, = *Leucosolenia coriacea*, Bk., together with a new Variety of *Leucosolenia lacunosa*, Bk., elucidating the Spicular Structure of some of the Fossil Calcispongiæ; followed by illustrations of the Pin-like Spicules on *Verticillites helvetica*, De Loriol, 17.—G. R. Vine. Notes on Species of *Ascodictyon* and *Rhopalonaria* from the Wenlock Shales, 77.—R. Kidston. On a new Species of *Lycopodites*, Goldenberg (*L. Stockii*), from the Calciferous-Sandstone Series of Scotland, 111.—A. de Quatrefages. Moas and Moa-hunters, 124, 159.—R. Etheridge, jun., and Arthur H. Foord. On two Species of *Alveolites* and one of *Amplexopora* from the Devonian Rocks of Northern Queensland, 175.—P. M. Duncan and W. P. Sladen. The Classificatory Position of *Hemiaster elongatus*, Duncan and Sladen: a Reply to a Criticism by Prof. Sven Lovén, 225.—S. H. Scudder. Triassic Insects from the Rocky Mountains, 254.—K. A. Zittel. On Astylospongidæ and Anomocladina, 271.—R. Etheridge, jun., and A. H. Foord. Descriptions of Palæozoic Corals in the Collections of the British Museum (Nat. Hist.), No. II., 314.—T. Rupert Jones. Notes on the Palæozoic Bivalved Entomostraca, No. XVII. Some North-American Leperditiæ and allied Forms, 339.—T. Rupert Jones. Notes on the Palæozoic Bivalved Entomostraca, No. XVIII. Some Species of the Entomididæ, 391.

——. ——. Vol. xv. Nos. 85–90. 1885. *Purchased.*

P. M. Duncan. On the Classificatory Position of *Hemiaster elongatus*, 72.

—G. Lindström. A Scorpion from the Silurian Formation of Sweden, 76. —F. W. Hutton. The Origin of the Fauna and Flora of New Zealand, 77.—G. J. Hinde. Description of a new Species of Crinoids with Articulating Spines, 157.—T. Rupert Jones. Notes on the Palæozoic Bivalved Entomostraca, No. XIX. On some Carboniferous Species of the Ostracodous Genus *Kirkbya*, Jones, 174.—C. Brongniart. On the Discovery of an Impression of an Insect in the Silurian Sandstone of Jurques (Calvados), 355.—R. Kidston. On some new or little-known Fossil Lycopods from the Carboniferous Formation, 357.—S. H. Scudder. New Genera and Species of Fossil Cockroaches from the Older American Rocks, 408.—R. Kidston. Notes on some Fossil Plants collected by Mr. R. Dunlop, Airdrie, from the Lanarkshire Coal-field, 473.

Art Union of London. Report of the Council for the year 1884. 1884.

Athenæum (Journal). Nos. 2957–2983. 1884.

——. Nos. 2984–3007. 1885.

——. Parts 678–684. 1884.

——. Parts 685–689. 1885.

Barnsley. Midland Institute of Mining, Civil, and Mechanical Engineers. Transactions. Vol. ix. Parts 72–74. 1884.

A. Lupton. Notes on a Visit to some Continental Mines, 287.

——. ——. ——. Vol. x. Part 75. 1885.

Basel. Société Paléontologique Suisse. Mémoires. Vol. xi. 1884. *Purchased.*

F. Korby. Monographie des polypiers jurassiques de la Suisse, 4e partie. —G. Millard. Monographie des invertébrés du Purbeck du Jura.—H. Haas. Etude monographique et critique des Brachiopodes Rhétiens et Jurassiques des Alpes Vaudoises et des contrées environnantes, 1e partie.

Bath. Natural-History and Antiquarian Field Club. Proceedings. Vol. v. No. 4. 1885.

Belfast. Natural-History and Philosophical Society. Report and Proceedings for 1883–84. 1884.

M. F. Heddle. On Agates, 14.

——. Naturalists' Field Club. Annual Report and Proceedings, 1883–84. Ser. 2. Vol. ii. Part 4. 1884.

J. S. Gardner. The Age of the Basalts of the North-east Atlantic, 254.

Berlin. Deutsche Geologische Gesellschaft. Zeitschrift. Band xxxvi. Hefte 1–4. 1884.

Fr. Pfaff. Zur Frage der Veränderungen des Meeresspiegels durch den Einfluss des Landes, 1.—A. Grabbe. Beiträge zur Kenntniss der Schildkröten des deutschen Wealden, 17.—G. R. Lepsius. Ueber ein neues Quecksilber-Seismometer und die Erdbeben im J. 1883 bei Darmstadt, 29.—S. Nikitin. Diluvium, Alluvium, Eluvium, 37.—E. von Dunikowski. Geologische Untersuchungen in Russisch-Podolien, 41.—E.

Tietze. Die Versuche einer Gliederung des unteren Neogen in den österreichischen Ländern, 68.—F. Sandberger. Ueber den Bimsstein und Trachyttuff von Schöneberg auf dem Westerwalde, 122.—G. Gürich. Ueber einige Saurier des oberschlesischen Muschelkalkes, 125.—H. Keilhack. Ueber postglaciale Meeresablagerungen in Island, 145.—H. Eck. Zur Gliederung des Buntsandstein im Odenwald, 161.—A. Jentzsch. Ueber Diatomeen-führende Schichten des westpreussischen Diluviums, 169.—A. G. Nathorst. Ueber cambrische Medusen, 177.—E. Beyrich. Erläuterungen zu den Goniatiten L. v. Buch's, 203.—G. Rammelsberg. Ueber die Gruppen des Skapoliths, Chabasits und Phillipsits, 220.—F. Schmidt. Einige Mittheilungen über die gegenwärtige Kenntniss der glacialen und postglacialen Bildungen im silurischen Gebiet von Ehstland, Oesel und Ingermanland, 248.—V. Uhlig. Ueber die Diluvialbildungen bei Bukowna am Dnjestr, 274.—G. Stache. Ueber die Silurbildungen der Ostalpen mit Bemerkungen über die Devon-, Carbon- und Perm-Schichten dieses Gebietes, 277.—K. Dalmer. Ueber das Vorkommen von Culm und Kohlenkalk bei Wildenfels unweit Zwickau in Sachsen, 379.—C. W. von Gümbel. Ueber die Beschaffenheit der Mollusken-Schalen, 383.—J. Felix. Korallen aus ägyptischen Tertiärbildungen, 415.—E. Holzapfel. Ueber einige wichtige Mollusken der Aachener Kreide, 454.—A. Wichmann. Ueber Gesteine von Labrador, 485.—E. Koken. Ueber Fisch-Otolithen, insbesondere über diejenigen der norddeutschen Oligocän-Ablagerungen, 500.—F. E. Geinitz. Ueber die Fauna des Dobbertiner Lias, 566.—A. Seeck. Beitrag zur Kenntniss der granitischen Diluvialgeschiebe in den Provinzen Ost- und Westpreussen, 584.—G. Vom Rath. Einige Wahrnehmungen längs der Nord-Pacific-Bahn zwischen Helena, der Hauptstadt Montanas, und den Dalles (Oregon) am Ostabhange des Kaskaden-Gebirges, 629.—A. von Groddeck. Zur Kenntniss der Zinnerzlagerstätte des Mount Bischoff in Tasmanien, 642.—F. J. P. van Calker. Beiträge zur Kenntniss des Groninger Diluviums, 713.—G. Böhm. Beiträge zur Kenntniss der grauen Kalk in Venetien, 737.—H. Vater. Die fossilen Hölzer der Phosphoritlager des Herzogthums Braunschweig, 783.—F. E. Geinitz. Ueber ein Graptolithen-führendes Geschiebe mit *Cyathaspis* von Rostock, 854.—C. E. Weiss. Ueber den Porphyr mit sogenannter Fluidal-Structur von Thal im Thüringer Wald, 858.—J. G. Bornemann, sen. *Cyclopelta Winteri*, eine Bryozoe aus dem Eifeler Mitteldevon, 864.—G. Berendt. Kreide und Tertiär von Finkenwalde bei Stettin, 866.—C. Gottsche. Auffindung cambrischer Schichten in Korea, 875.—K. Dalmer. Ueber den Kohlenkalk von Wildenfels in Sachsen, 876.

Berlin. Deutsche Geologische Gesellschaft. Zeitschrift. Band xxxvii. Heft 1. 1885.

Branco. Ueber die Anfangskammer von Bactrites, 1.—A. Becker. Schmelzversuche mit Pyroxenen und Amphibolen und Bemerkungen über Olivinknollen, 10.—F. Frech. Die Korallenfauna des Oberdevons in Deutschland, 21.—T. Fuchs. Die Versuche einer Gliederung des unteren Neogen im Gebiete des Mittelmeers, 131.—M. Verworn. Ueber *Patellites antiquus*, Schloth, 173.—G. de Geer. Ueber die zweite Ausbreitung des skandinavischen Landeises, 172.—E. Kayser. *Lodanella mira*, eine unterdevonische Spongie, 207.—E. Koken. Ueber *Ornithocheirus hilsensis*, Koken, 214.

——. Königlich-Preussische Akademie der Wissenschaften. Sitzungsberichte, 1884. Nos. 18–54. 1884–85.

H. Bucking. Ueber die Lagerungsverhältnisse der älteren Schichten in Attika, 935.

Berlin. Palæontologische Abhandlungen. Band ii. Hefte 2 & 3. 1884. *Purchased.*

H. Graf zu Solms-Laubach. Die Coniferenformen des deutschen Kupferschiefers und Zechsteins (Heft 2).—W. Dames. Ueber Archaeopteryx (Heft 3).

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F. Nötling. Die Fauna der baltischen Cenoman-Geschiebe.

Birmingham. Midland Naturalist. N. S. Vol. vii. Nos. 79 & 80. 1884. *Presented by Wm. Whitaker, Esq., F.G.S.*

H. Pearce. Ice Action in the Valley of the Artro, 197.

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38 N.W., N.E., S.W., S.E.; 40 N.W., N.E., S.W.; 43 N.W., N.E., S.W., S.E.; 44 N.W., N.E., S.W.; 45 S.E.; 46 N.W., N.E., S.W., S.E.; 47 N.W., N.E.; 49 S.E.; 50 N.W., N.E., S.W., S.E.; 51 N.W., N.E., S.W., S.E.; 52 N.W., N.E., S.W., S.E.; 53 N.W., N.E., S.W.; 54 N.W., N.E., S.W., S.E.; 55 N.W., N.E., S.W., S.E.; 56 N.W.; 58 N.W., N.E.; 59 S.E.; 62 N.W., S.W., S.E.

Northamptonshire & Warwickshire. Qu.-sh. 29 N.W. & 29 N.W., 29 S.W. & 29 S.W., 35 N.E. & 35 N.E., 35 S.E. & 35 S.E., 42 N.E. & 41 N.E., 42 S.W. & 41 S.W., 42 S.E. & 41 S.E., 49 N.W. & 47 N.W., 49 N.E. & 47 N.E., 49 S.W. & 47 S.W., 92 S.W. & 6 S.W., 99 N.E. & 9 N.E.

Nottinghamshire. Quarter-sheets 18 N.W., N.E., S.W., S.E.; 19 N.W., N.E., S.W., S.E.; 20 N.W., S.W.; 23 N.E., S.W., S.E.; 24 N.W., N.E., S.W., S.E.; 25 N.W., N.E., S.W., S.E.; 26 S.W.; 28 N.E., S.E.; 29 N.W., N.E., S.W., S.E.; 30 N.W., N.E., S.W., S.E.; 31 N.W., S.W.; 33 N.W., N.E.; 34 N.W., N.E., S.W., S.E.; 35 N.W., S.W., S.E.; 36 N.W., S.W.; 39 N.E.; 41 N.E., S.E.; 44 N.W.; 47 N.W., S.W.; 50 N.W.

—— and Derby. Quarter-sheet 32 N.W. & 41 N.W.

—— and Leicester. Quarter-sheets 41 S.W. & 32 S.W., 50 N.E. & 11 N.E., 50 S.W. & 11 S.W., 50 S.E. & 11 S.E., 51 N.W. & 12 N.W., 56 N.E. & 45 N.E.

—— and Lincoln. Quarter-sheets 28 N.E. & 68 N.E., 21 N.E. & 69 N.E., 21 S.E. & 69 S.E., 53 N.W. & 28 N.W.

Oxfordshire. Sheets 21, 26, 30, 31.

—— and Berkshire. Sheets 37 and 4, 46 and 11.

—— and Buckinghamshire. Sheets 28 and 24, 50 and 45, 53 and 50.

—— and Wiltshire. Sheet 36 and 2 A.

Rutlandshire. Quarter-sheets 3 S.W., S.E.; 5 N.W., N.E., S.W., S.E.; 6 N.W., N.E., S.W., S.E.

Shropshire. Quarter-sheets 1 S.E.; 4 S.W.; 5 N.E., S.W., S.E.; 6 S.W., S.E.; 7 S.W., S.E.; 8 N.E., S.E.; 9 N.W., N.E., S.W.; 11 N.E., S.E.; 12 N.W., S.W.; 13 N.W., N.E., S.W., S.E.; 14 N.W., N.E., S.W., S.E.; 15 N.W., N.E., S.W.; 16 N.E., S.W.; 17 N.W.; 18 N.E.; 19 N.E., S.W., S.E.; 20 N.W., N.E.; 21 N.W., N.E., S.W., S.E.; 22 N.W., S.W., S.E.; 23 N.W., N.E., S.W., S.E.;

24 N.W., S.W., S.E.; 25 N.E.; 26 S.W.; 27 N.W., N.E., S.W., S.E.; 28 N.W., N.E., S.E.; 29 N.W., N.E.; 30 N.E., S.W.; 31 N.W., S.W.; 34 N.E., S.W., S.E.; 35 N.W., S.W., S.E.; 36 N.W.; 40 S.W.; 43 S.W.; 49 N.W.; 73 N.E.; 75 N.E.; 76 N.E., S.W., S.E.; 79 N.E., S.E.

Shropshire and Herefordshire. Quarter-sh. 77 N.W. & 2 N.W., 77 N.E. & 2 N.E., 77 S.W. & 2 S.W., 78 N.W. & 3 N.W., 78 N.E. & 3 N.E., 78 S.E. & 3 S.E., 79 S.W. & 4 S.W., 82 N.W. & 7 N.W., 83 N.W. & 8 N.W.

—— and Montgomeryshire. Quarter-sh. 53 S.E. & 37 S. E., 61 N.E. & 44 N.E., 61 S.W. & 44 S.W., 61 S.E. & 44 S.E., 68 N.W. & 49 N.W.

Somersetshire. Quarter-sheets 1 S.E.; 2 N.W., N.E., S.W., S.E.; 3 S.W.; 4 N.W., N.E., S.W., S.E.; 5 N.W., N.E., S.W., S.E.; 6 N.W., N.E., S.W., S.E.; 7 N.W., N.E., S.W., S.E.; 8 N.W., S.W., S.E.; 10 N.W., N.E., S.W., S.E.; 11 N.W., N.E., S.W., S.E.; 12 N.W., N.E., S.W., S.E.; 13 N.W., N.E., S.W., S.E.; 14 N.E., S.E.; 16 N.W., S.W., S.E.; 17 N.W., S.E.; 18 N.W., N.E., S.W., S.E.; 19 N.W., N.E., S.W., S.E.; 20 N.W., S.W.; 21 N.W., N.E., S.W., S.E.; 24 N.E., S.E.; 25 N.W., N.E., S.E.; 26 N.W., N.E., S.E.; 27 N.W., N.E., S.W., S.E.; 28 N.W., N.E.; 29 N.E., S.E.; 30 N.W., N.E.; 31 N.W.; 42 N.E., S.E.

Staffordshire. Quarter-sheets 2 S.W.; 3 S.W.; 7 N.E.; 8 N.W.; 10 N.W.; 12 S.E.; 15 S.E.; 31 S.E.; 32 N.W., S.W.; 38 S.E.; 39 N.W.; 40 N.W., S.W.; 43 N.E., S.W., S.E.; 44 S.W.; 45 N.W.; 46 N.W., N.E., S.W., S.E.; 47 N.W.; 49 N.W., N.E., S.W.; 50 N.E., S.W., S.E.; 56 N.E.; 59 S.W.; 61 N.W., N.E., S.W., S.E.; 66 N.W., N.E.; 68 N.E., S.W., S.E.; 70A S.E.

—— and Derbyshire. Quarter-sheet 14 S.E. & 37 S.E.

—— and Warwickshire. Quarter-sheets 59 S.E. & 2 S.E., 64 N.W. & 4 N.W., 64 N.E. & 4 N.E., 64 S.W. & 4 S.W., 65 N.W. & 5 N.W., 65 N.E. & 5 N.E., 69 N.W. & 8 N.W., 71 S.W. & 6 S.W., 73 N.E. & 7 N.E., 74 S.W. & 8 S.W.

Suffolk. Quarter-sheets 10 S.E.; 17 N.E.; 22 S.E.; 23 N.W., S.E.; 27 N.W.; 32 N.E., S.E.; 33 N.W., S.E.; 34 S.E.; 38 N.W., S.W., S.E.; 39 N.E., S.E.; 40 N.W., S.W.; 43 N.E.; 44 N.W., S.W., S.E.; 45 N.W., N.E., S.W., S.E.; 47 N.W., N.E., S.W., S.E.; 48 N.W., N.E.,

S.W., S.E.; 49 N.W.; 50 N.W., S.E.; 51 N.W.; 53 N.E., S.E.; 54 N.E., S.W., S.E.; 55 N.W., N.E., S.W., S.E.; 56 S.W., S.E.; 57 N.W., N.E., S.W., S.E.; 58 N.W., N.E., S.W., S.E.; 59 N.E., S.W., S.E.; 60 S.W.; 63 N.W., N.E., S.W., S.E.; 64 N.W., N.E., S.W., S.E.; 65 N.W., N.E., S.W.; 66 N.W., N.E.; 69 N.W.; 70 S.W.; 74 S.W.; 75 N.W., N.E., S.E.; 76 N.W., N.E.; 82 N.W., N.E.; 85 N.W.

Suffolk and Cambridgeshire. Quarter-sh. 31 N.E. & 36 N.E., 31 S.W. & 36 S.W., 31 S.E. & 36 S.E., 32 S.W. & 37 S.W., 42 N.E. & 42 N.E., 42 S.E. & 42 S.E.

—— and Norfolk. Quarter-sheets 2 N.W. & 78 N.W., 4 S.W. & 90 S.W., 7 S.W. & 93 S.W., 9 S.E. & 99 S.E., 10 S.W. & 100 S.W., 17 N.W. & 107 N.W.

Warwickshire. Quarter-sheets 17 N.W.; 50 S.W.; 57 S.W.

—— & Worcestershire. Quarter-sheets 24 N.W. & 31 N.W., 30 N.E. & 23 N.E., 30 S.E. & 23 S.E., 36 N.E. & 30 N.E., 36 S.E. & 30 S.E., 42 N.E. & 35 N.E., 48 N.E. & 42 N.E.

Worcestershire. Quarter-sheets 8 S.E.; 9 N.E., S.W., S.E.; 10 N.W., N.E., S.E.; 12 N.E., S.W., S.E.; 13 N.W., N.E., S.W., S.E.; 15 S.E.; 16 S.W.; 18 N.E., S.E.; 19 N.W., N.E., S.W., S.E.; 20 N.W., N.E., S.W., S.E.; 21 N.W., S.W., S.E.; 22 N.E., S.W., S.E.; 23 N.W., S.W.; 25 N.E.; 26 N.W., N.E.; 27 N.E., S.W., S.E.; 28 N.W., N.E., S.W.; 29 N.W., N.E., S.W., S.E.; 30 N.W., S.W.; 31 S.E.; 32 N.W., N.E., S.W., S.E.; 33 N.W., S.W.; 34 N.W., N.E., S.W., S.E.; 35 S.W.; 38 N.E.; 39 N.W.; 40 N.W., N.E., S.E.; 41 N.W., N.E., S.W., S.E.; 42 S.W.; 48 N.E.

—— and Gloucester. Quarter-sheets 48 S.W. & 5 S.W., 48 S.E. & 5 S.E., 49 N.W. & 6 N.W., 50 N.W. & 7 N.W., 50 N.E. & 7 N.E., 50 S.W. & 7 S.W., 50 S.E. & 7 S.E., 54 N.E. & 11 N.E.

——, Warwickshire, and Gloucestershire. Quarter-sheets 43 N.W., 49 N.W., & 3 N.W.; 44 N.E., 50 N.E., & 4 N.E.

Paris. *Dépôt de la Marine.* 15 Sheets of Charts and Plans of various Coasts, &c.

Russia. *Geological Committee.* Sheet 71. $\frac{1}{420000}$.

Russia. *Geological Committee.* Geologische Karte des Ostabhanges des Urals, von A. Karpinsky, in 3 sheets. $\frac{1}{420000}$.

Saxony. *Geologische Landesuntersuchung des Königreichs Sachsen.* Geologische Specialkarte. Blatt Mutzschen, 29; Kirchberg, 125; Zoblitz, 129; Schwarzenberg, 137; Eibenstock, 145; Wiesenthal, 147. $\frac{1}{25000}$.

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——. ——. Ser A. *b*, 10. $\frac{1}{50000}$.

——. ——. Karta öfver berggrunden inom norra delen af Kalmar län utförd på bekostnad af lanets norra Hushallnings Sällskap. $\frac{1}{200000}$.

——. ——. Geologisk Öfversigtskarta öfver Sverige. Södra bladet. $\frac{1}{1000000}$.

Switzerland. *Geological Commission.* Sheet 18. $\frac{1}{100000}$.

II. ADDITIONS TO THE MUSEUM.

Specimens illustrating the paper on the Serpentine of Porthalla Cove, in Q. J. G. S. vol. xl. p. 458. *Presented by J. H. Collins, Esq., F.G.S.*

Two slides with Cretaceous Lichenoporidæ, illustrating the paper in Q. J. G. S. vol. xl. p. 850. *Presented by G. R. Vine, Esq.*

Casts of Footprints in the Lower New Red Sandstone of Penrith, illustrating the paper in Q. J. G. S. vol. xl. p. 479. *Presented by G. V. Smith, Esq., F.G.S.*

Specimens illustrating Mr. A. W. Waters's paper on Chilostomatous Bryozoa from Muddy Creek, Victoria (Q. J. G. S. vol. xxxix. p. 423). *Presented by J. B. Wilson, Esq.*, of Geelong.

A specimen of Fulgurite from Mont Blanc, illustrating the paper in Q. J. G. S. vol. xli. p. 152. *Presented by F. Rutley, Esq., F.G.S.*

Ten Sandworn Stones from Hokitika, New Zealand. *Presented by W. D. Campbell, Esq., F.G.S.*

Six slides of Cyclostomatous Bryozoa from Muddy Creek, South Australia, illustrating the paper in Q. J. G. S. vol. xl. p. 674. *Presented by J. B. Wilson, Esq., F.G.S.*